COAL METAL MINERS POCKETBOOK

PRINCIPLES, RULES, FORMULAS,
AND TABLES.

SPECIALLY COMPILED AND PREPARED FOR THE CONVENIENT USE OF MINE OFFICIALS, MINING ENGINEERS, AND STUDENTS PREPARING THEMSELVES FOR CERTIFICATES OF COMPETENCY AS MINE INSPECTORS OR MINE FOREMEN.

SIXTH EDITION: REVISED AND ENLARGED,

WITH

ORIGINAL MATTER.

"Though index learning turns no student pale, It grasps the Eel of Science by the tail." Pope.

SCRANTON, PA.: THE COLLIERY ENGINEER COMPANY. 1900. TRANSFERRED TO
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May 13.1931

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THE COLLIERY ENGINEER COMPANY, SCRANTON, PA., U. S. A.

PREFACE.

The fifth edition of The Coal and Metal Miners' Pocketbook was very kindly received, and the criticisms of it were most friendly and flattering.

The sixth edition has been compiled under particularly favorable circumstances and is much more complete than any

previous edition.

Prominent engineers and manufacturers of mining machinery throughout the world have kindly criticized the previous edition, have suggested wherein it could be improved, and have sent to us information from their private note books that has never before been published.

The staff of MINES AND MINERALS, the large force of Mining, Mechanical, and Electrical Engineers connected with The International Correspondence Schools, and many other engineers and mine managers have contributed to it.

All this material has been carefully sifted, verified wherever possible, and combined with the data in the former edition. By careful selection and rewriting, or by different methods of presentation, it has been possible to include essentially all that was in the fifth edition, and at the same time to add from one-third to one-half again as much entirely new matter, without materially increasing the size of the book.

Every portion of the fifth edition has been either entirely rewritten, or revised, enlarged, and brought up to date. New illustrations have been drawn, and the entire book has been printed from new plates.

The sections on Mathematics and Surveying have been amplified by the addition of new tables and by text treating of the Solar Transit and Rocky Mountain methods of surveying.

The sections on Hydraulics; the Application of Electricity to Mining; Timbering, Haulage, Blasting, Ore Dressing, and Coal Washing are entirely new.

iii

The sections on Prospecting, Ventilation, and Methods of Working have been entirely rewritten, enlarged, and greatly improved.

The tables of Logarithms, Trigonometric Functions, etc. have been reset from the latest corrected editions of standard tables. The Traverse Table has been greatly reduced in length, but without affecting its efficiency, while the table of Squares, Cubes, etc. has been added to by the addition of Circumferences and Areas of Circles.

The-Glossary, which contains about 2,500 words, is believed to be the most complete mining glossary ever published, as it is a combination of all the mining glossaries extant of which the compilers could hear.

Wherever possible, credit has been given the authorities from whom data have been taken, but in such a work it is manifestly impossible to give full credit for everything that has been extracted, quoted, and compiled, and we can only in this very general way acknowledge our indebtedness to the large number of authors and engineers whom we have failed to mention by name in the text.

No one appreciates as fully as does the editor of such a publication the value of the suggestions and data that have been so generously furnished to assist us in the compilation. We shall be greatly obliged to all readers of this volume who may call our attention to any errors that they may discover, or to the omission of any data that they may feel the lack of, so that attention may be given to these matters in future editions.

TABLE OF CONTENTS.

(For detailed Index, see back of volume. See also Glossary of Mining Terms, page 565.)

WEIGHTS AND MEASURES.

THE METRIC SYSTEM. -1.

- WEIGHTS.—Troy, 1: Apothecaries', 1: Avoirdupois, 2: Metric, 2.
- MEASURES OF LENGTH.—American and British, 2; Reduction of Inches to Decimals of a Foot, 2; Decimals of a Foot for Each 1 of an Inch, 3; Metric, 3; Russian, 3; Prussian, Danish, and Norwegian, 3; Austrian, 3; Swedish, 4; Chinese, 4. •
- MEASURES OF AREA.—American and British, 4; Table for Reducing Square Feet to Acres, 4; Metric, 4.
- MEASURES OF VOLUME,—American and British, 5; Metric, 5; Liquid (U. S.), 5; Dry (U. S.), 5; British Imperial (Liquid and Dry), 5; Contents of Cylinders or Pipes for 1 Foot in Length, 6; Mexican, Central American, and South American Weights and Measures, 7.
- CONVERSION TABLES.—Customary to Metric, 7; Metric to Customary, 9.
- MONEY.—United States, 10; British, 10; Standard U. S. Coins, Weights and Fineness, Space Required to Store, 10; Conversion of English and American Money Values, 11; Value of Foreign Coins, U. S. Treasury Department, 11; Carat Measures, 12.
- Timber and Board Measure,—Rule for Measuring. 12; Timber Measure, 12; Round Timber, Table of ‡ Girths, 13; Board Measure, 13.
- MATHEMATICS.—General Principles, 14; Signs and Abbreviations, 14.
- ARITHMETIC.—To Cast the Nines Out of a Number, 15; To Prove Addition, Subtraction, Multiplication, and Division, 15; Common Fractions, 15; Decimals, 16; Simple and Compound Proportion, 18; Involution, 19; Evolution, 19; Percentage, 20; Arithmetical Progression, 20; Geometrical Progression, 21; Logarithms, 22.
- GEOMETRY.—Principles, 24; Practical Problems in Geometrical Construction, 25.
- MENSURATION. -Surfaces, 28; Solids, 33; Prismoidal Formula, 34.
- PLANE TRIGONOMETRY.— Principles of Trigonometry, 34; Practical Examples in the Solution of Triangles, 35.
- SURVEYING.—The Compass, 38; Adjustments, 38; Use of Compass, 39; Magnetic Variation, 39; Tisogonic Chart, 39; The Vernier, 39; The Transit, 40; Adjustments, 41; The Chain, or Steel Tape and Pins, 42; Plumb-Bob, 44; The Clinometer or Slope Level, 44; Field Notes for an Outside Compass Survey, 44; Transit Surveying, 45; Determination of Meridian by Polaris, 46; Determination of Meridian With Solar Attachment, 47; Use of Solar Attachment, 47; General Remarks, 49; Plotting, 49; Coordinates, 51; Contents of Coal Seam, 52; Leveling, 53; Adjustments, 58; Use of Level, 54; Field Work 54; Notes, 55; Tigonometric Leveling, 56; Underground Surveying, 56; Establishment and Marking of Stations, 57; Centers, 59; Notes, 60; Stope Books, 62; Mine Corps, 66; Surveying Methods, 67; Outside Surveys, 67; Inside Surveys, 67; Closing Surveys, 68; Connecting Outside and Inside Works Through Shafts and Slopes, 68; Notes on Mapping, 74; Locating Errors, 76; Locating Special Work, 77; Calculation of Areas, 77; Railroad Curves, 78; Hints to Beginners, 80; Theory of Stadia Measurements, 81; Tables, 88.

ELEMENTS OF MECHANICS.—Levers, 91; Wheel and Axle, 92; Inclined Plane, 93; Screw, 93; Wedge, 93; Pulleys, 94; Composition of Forces, 95.

FRICTION.—Coefficients, 95; Shafting, 96; Friction of Mine Cars, 96.

LUBRICATION.—Best Lubricants for Different Purposes, 102.

APPLIED MECHANICS.

- STRENGTH AND WEIGHT OF MATERIALS.—Wooden Beams, 102; Iron and Steel Beams, 103; Structural-Steel I Beams, 104; Pillars or Proper 105; Cast-Iron Columns, 106; Specific Gravity, Weight, and Properties of Materials, 107; Line Shafting, 110; Weight of Castings, Sheets, and Plates, 111; Weight of Cast-Iron Pipe per Foot in Pounds, 113; Wood Screws, 113; Weight of Wrought Iron, 114; Iron Required for 1 Mile of Track, 117; Rails, Splices, and Bolts for 1 Mile of Track, 117.
- Wire Ropes, —General Remarks, 118; Flat Ropes, 119; Standard Hoisting Ropes, 120; Transmission or Haulage Rope, 122; Stress in Hoisting Ropes, 125; Relative Effects of Various Sheaves on Wire Rope, 125; Working Load for Hoisting Ropes, 125; Starting Strain, 126; Horsepower of Manila Ropes, 126; Rapid Method of Splicing a Wire Rope, 127; Ordinary Long Splice, 129; Chains, 129.
- HYDROSTATIOS,—General Principles, 130; Equilibrium of Liquids, 130; Pressures of Liquids on Surfaces, 130; Pressure Exerted by Quiet Water Against the Side of a Gangway or Heading, 130; Total Pressure of Quiet Water Against and Perpendicular to Any Surface Whatever, 131; Transmission of Pressure Through Water, 132; Pressure at Any Given Depth, 132; Pressure of Water in Pipes, 132; Construction of Mine Dams, 133.
- 132; Pressure of Water in Pipes, 132; Construction of Mine Dams, 133.

 Hydraulics —General Principles, 135; Theoretical Velocity of a Jet of Water, 135; Theoretical Quantity of Water Discharged in a Given Time, 135; Flow of Water Through Orifices, 135; Coefficients of Contraction, Velocity, Discharge, 135; Suppression of the Contraction, 136; Gauging Water, 136; Miners' Inch, 136; Duty of a Miners' Inch of Water, 137; Right-Angled V Notch, 137; Discharge of Water Through a Right-Angled V Notch, 138; Gauging by Weirs, 138; Coefficient of Discharge for Weirs With and Without End Contractions, 140; Weir Table Giving Cubic Feet Discharged per Minute, 141; Conversion Factors, 141; Flow of Water in Open Channels, 142; Ditches, 142; Safe Bottom Velocity, 142; Resistance of Soils to Erosion by Water, 143; Carrying Capacity of Ditches, 143; Grade, 143; Ditch Banks, 143; Influence of Depths on Ditch, 144; Measuring the Flow of Water in Channels, 144; Flow in Brooks and Rivers, 145; Flumes, 146; Grade and Form, 145; Timber Flumes, 145; Connection With Ditches, 146; Trestles, 146; Curves, 146; Waste Gates, 146; Flow of Water Through Flumes, 146; Tunnels, 147; Flow in Pipes, 147; Flow of Water Through Flumes, 146; Frondient, 147; Flow in Pipes, 147; Siphons, 149; Table Showing Actual Flow in Pipes From § 'to 30" Dismeter, 150; Loss of Head in Pipe by Friction, 151; Friction of Knees and Bends, 153; Reservoir Site, 154; Dams, 154; Spullways or Wasteways, 155; Stone Dams, 155; Earth Dams, 156; Wing Dams, 156; Masonry Dams, 156; Theoretical Efficiency of a Water-Power, 156; Horsepower of a Running Stream, 157; Current Motors, 157; Breast and Undershot Wheels, 157; Overshot Wheels, 158; Impulse Wheels, 158; Turnbes, 158.

 Pump Machinery,—Cornish Pumps, 158; Simple and Duplex Pumps,
- PUMP MACHINERY—Cornish Pumps, 158; Simple and Duplex Pumps, 158; Packing, 159; Speed of Water Through Valves, Pipes, and Pump Passages, 160; Ratio of Steam and Water Cylinders in the Direct-Acting Pump, 160; Piston Speed of Pumps, 161; Boiler Feed-Pumps, 161; Theoretical Capacity of Pumps and the Horsepower Required to Raise Water, 161; Depth of Suction, 162; Amount of Water Raised by a Single-Acting Lift Pump, 162; Pump Valves, 162; Power Pumps, 162: Electrically Driven Pumps, 162: Table Giving Water Delivered per Minute for Various Sized Pumps, 163; Miscellancus Forms of Water Elevators, 164; Air-Lift Pumps, 164; Vacuum Pumps, 164; Water Buckets, 164; Sinking Pumps, 165; Pumps for Acid Water, 165.

FORMS OF POWER.

- Fuels.—Table of Combustibles, 166; Analyses and Heating Values of American Coals, 168; Thermal Unit, 168; Composition of Fuels, 169; Classification, Composition, and Properties of Coals, 169; Weights and Measurements of Coal, 170; Coke, 172; Analysis of Coal, 173.
- STEAM.—High-Pressure Steam, 175; Expansion of Steam, 176: Condensers, 176.
- BOILERS.—Lancashire Boiler, 177; Horsepower of Boilers, 177; Heating Surface, 177; Choice of a Boiler, 179; Explosions, 179; Questions to Be Asked Concerning New Boilers, 180; Incrustation and Scale, 182; Covering for Boilers, Steam Pipes, Etc., 188; Data for Proportioning an Economizer, 185; Care of Boilers, 185; Thickness of Boiler Iron, 187; Pressure of Steam at Different Temperatures, 188; Maximum Economy of Plain Cylinder Boilers, 188; Scheme for Boiler Test, 188; Chimneys, 189.
- STEAM ENGINES.—What Is a Good Engine? 190; Determination of M. E. P., 190; Rules for Engine Drivers, 191; Belting and Velocity of Pulleys, 193.
- COMPRESSED AIR.—Classification of Compressors, 194; Construction of Compressors, 194; Theory of Air Compression, 194; Rating of Compressors, 195; Cooling, 195; Dry Versus Wet Compressor, 196; Transmission of Air in Pipes, 196; Losses in the Transmission of Compressed Air, 198; Friction of Air in Pipes, 201; Loss of Pressure in Pounds per Square Inch, by Flow of Air in Pipes, 202; Loss by Friction in Elbows, 208.
- ELECTRICITY.—Practical Units, 203: Strength of Current, 203: Electric Pressure or Electromotive Force, 203; Resistance, 203; Power, 204; Circuits, 205; Series Circuits, 205; Parallel Circuits, 206; Series Circuits, 205; Parallel Circuits, 206; Resistance in Series and Multiple, 206; Shunt, 207; Electric Wiring, 207; Materials, 207; Forms of Conductors, 207; Wire Gauge, 207; Estimation of Cross-Section of Wires, 207; Properties of Copper Wire, 208; Properties of Aluminum and Copper, 209; Estimation of Resistance, 209; Calculation of Wires for Electric Transmission, 210; Current Estimates, 212; Incandescent Lamps, 214; Motors, 214; Conductors for Electric-Haulage Plants, 214; Dynamos and Motors, 215; Direct-Current Dynamos, 215; Factors Determining E. M. F. Generated, 218; Field Excitation of Dynamos, 218; Series-Wound Dynamos, 219; Shunt-Wound Dynamos, 219; Compound-Wound Dynamos, 219; Direct-Current Motors, 220; Principles of Operation, 220; Speed Regulation of Motors, 222; Connections for Continuous-Current Motors, 223; Alternating-Current Dynamos, 224; Single-Phase Alternators, 225; Multiphase Alternators, 225; Synchronous Motors, 226; Induction Motors, 227, Transformers, 228; Electric Signaling, 229; Batteries, 229; Bell Wiring, 230; Special Mine Applications, 233; Telephones, 233.

MINING.

PROSPECTING.—Outfit Necessary, 235: Plan of Operations, 236; Geological Table, 237; Coal or Bedded Materials, 238; Formations Likely to Contain Coal, 238; Ore Deposits, 238; Position of Veins and Ore Deposits, 239; Underground Prospecting, 239; Prospecting for Placer Deposits, 240; Value of Free Gold per Ton of Quartz, 241; Gems and Precious Stones, 241; Exploration by Drilling or Bore Holes, 242; Earth Augers, 242; Percussion or Churn Drills, 242; The Diamond Drill, 243; Selecting the Machine, 243; Size of Tools, 243; Drift of Diamond-Drill Holes, 243; The Surveying of Diamond-Drill Holes, 243; The Value of the Record Furnished by the Diamond Drill, 244; The Arrangement of Holes, 244; The Cost and Speed of Drilling, 244; Records of Cost per Foot in Diamond Drilling, 246; Cost of Operation per Month of Bed-Rock Exploration, 247; Magnetic Prospecting, 248; Prospecting for Petroleum, Natural Gas, and Bitumen, 249; Construction of Geological Maps and Cross-Sections, 249; To Obtain Dip and Strike From Bore-Hole Records, 250; Sampling and Estimating the Amount of Mineral Available, 251; Diagram for Reporting on Mineral Lands, 252.

- OPENING A MINE.—Opening a Gold Mine, 258; Form of Shafts, 259; Compartments, 259; Shaft Sinking, 259; Size of Shaft, 259; Forepoling, 260; Metal Linings Forced Down, 260; Pneumatic Method of Shaft Sinking, 260; Freezing Frocess, 260; Table of Well-Known Shafts, 261; Kind-Chaudron Method, 262; Long-Hole Process, 262; Comparison of Methods of Shaft Sinking, 262; Sinking Head-Frames, 262; Sinking Engines, 263; Tools, 263; Speed and Cost of Sinking, 263; Slope Sinking, 263; The Sump, 264; Driving the Gangway, 264; Levels in Metal Mines, 264; Mining Tunnels, 265.
- MINE TIMBER AND TIMBERING.—Choice of Timber, 265; Preservation of Timber, 265; Placing of Timber, 266; Size of Timber, 267; Joints in Mine Timbering, 267; Undersetting of Props, 267; Forms of Mine Timbering and Underground Supports, 267; Gangway or Level Timbers, 268; Shaft Timbering, 270; Square Sets, 270; Landing, Plats, or Stations, 272; Special Forms of Supports, 272; Iron and Steel Supports, 272; Trestles, 274; Timber Head-Frames or Head-Gears, 275; Steel Shaft Bottoms, 276.
- Bottoms, 276.

 METHODS OF WORKING.—Open Work, 277; Steam-Shovel Mines, 278; Milling, 278; Cableways, 278; Placers, 278; Hydraulicking, 278; Dredging, 279; Closed Work, 279; Bedded Deposits, 279; Coal Mining, 279; Boof Pressure, 280; Character of Floor, 280; Systems of Working Coal, 280; Room-and-Pillar System, 280; Longwall Method, 281; Panel System, 283; Control of Roof Pressure, 284; Number of Entries, 284; Direction of Face, 284; Size of Pillars, 285; Room Pillars, 286; Barrier Pillars, 287; Weight on Pillars in Pounds per Square Inch, 287; Drawing Pillars, 289; Compressive Strength of Anthracite, 290; Gob Fires, 291; Spontaneous Combustion, 291; Coal Storage, 291; Modifications of Room-and-Pillar Methods, 291; Buggy Breasts, 291; Chute Breasts, 292; Pillar-and-Stall, 292; Connellsville Region, 295; West Virginia, 296; Clearfield Region, 295; Reynoldsville Region, 295; West Virginia, 296; Alabama Methods, 297; George's Creek, 297; Blossburg Region, Pa., 289; Indiana Mining, 299; Tesla, California, Method, 300; New Castle, Colorado, Method, 302; Modifications of Longwall Methods, 302; Overhand Stoping, 304; Methods of Mining Anthracite, 305; Brown's Method, 306; Battery Working, 307; Single-Chute Battery, 309; Double-Chute Battery, 309; Rock-Chute Mining, 310; Williams' Method, 312; Running of Coal, 312; Hints for Working Thin Seams, 313; Flushing of Culm, 314; Methods of Mining Mineral Deposits, 316; Winzes, 316; Raises, 316; Stoping, 316; Flat Deposits, 318; Large Deposits, Over 8 Feet Thick, 318; Square Work, 318; Filling, 319; Slicing, 319; Transverse Rooming With Filling, 319; Caving, 320; Square-Set System, 321; Irregular Deposits, 321; Coyoting, 321; Special Methods, 322; Frozen Ground, 322; Leaching, 322; Costs of Mining Anthracite, 323; Lehigh Region (Pa.), 325; Wyoming Region (Pa.), 325; Prices of Coal, 326; Cost of Coking Coal, 328.
- Explosives. Low Explosives, 329; High Explosives, 329; Thawing Dynamite, 329; Common Blasting Explosives, 330; Drilling, 330; Diameter of Hole, 330; Amount of Charge, 331; Tamping, 331; Firing, 331: Detonators, 332; Electric Firing, 332; Power of an Explosive, 334: Arrangement of Drill Holes, 335.
- MACHINE MINING.—Pick Machines, 336; Chain-Cutter Machines, 337; Shearing, 337; Capacity, 337.
- VENTILATION OF MINES.—Atmosphere, 337; Atmospheric Pressure, 339; Barometric Variations, 339; Barometers, 339; Water Column Corresponding to Any Mercury Column, 340; Barometric Elevations, 340; Chemistry of Gases, 341; Absolute Temperature, 344; Absolute Pressure, 345; Diffusion and Transpiration, 346; Gases Found in Mines, 348; Constants for Mine Gases, 349; Gas Feeders, 352; Pressure of Occluded Gases, 352; Amount of Gas, 352; Outbursts of Gas, 352; Testing for Gas by Lamp Flame, 354; Safety Lamps, 355; Lamps for Testing, 355; Detection of Small Percentages of Gas, 356; Oils for Safety Lamps, 356; Types of Safety Lamps, 356; Cleaning Safety Lamps, 358; Relighting Stations, 359; Illuminating Power of Safety Lamps, 358; Explosive Conditions in Mines, 359; Derangement of Ventilating Current, 359; Sudden Increase of Gas, 360; Effect of Coal Dust in Mine

Workings, 360; Pressure as Affecting Explosive Conditions, 261; Rapid Succession of Shots in Close Workings, 361; Mine Explosions, 361; Recoil of an Explosion, 361; Exploring Workings After a Serious Explosion, 361; Quantity of Air Required for Ventilation, 362; Elements in Ventilation, 363; Power of the Current, 363; Mine Resistance, 364; Velocity of the Air-Current, 364; Measurement of Ventilating Currents, 364; Water Gauge, 365; Thermometers, 366; Calculation of Mine Resistance, 366; Calculation of Power or Units of Work per Minute, 367; Equivalent Orlice, 367; Potential Factor of a Mine, 367; Formulas, 370; Variation of the Elements, 372; Practical Splitting of the Air-Current, 373; Primary Splitts, 374; Secondary Splitts, 374; Tertiary Splitts, 374; Equal Splits of Air, 374; Unequal Splits of Air, 374; Natural Division of the Air-Current, 375; Box Regulator, 375; Box Regulator, 375; Dox Regulator, 375; Splitting Formulas, 378; Methods and Appliances in the Ventilation of Mines, 381; Ascensional Ventilation, 381; General Arrangement of Mine Plan, 381; Natural Ventilation, 381; Ventilation of Rise and Dip Workings, 382; Influence of Seasons, 382; Construction of a Mine Purnace, 383; Air Columns in Furnace Ventilation, 384; Inclined Air Columns, 384; Calculation of Ventilating Pressure in Furnace Ventilation, 386; Vacuum System of Ventilation, 386; Plenum Systems, 386; Types of Centrifugal Fans, 387; Manometrical Efficiency, 390; Fan Contruction, 391; High-Speed and Low-Speed Motors, 392; Fan Testa, 392; Conducting Air-Currents, 394.

- Hoisting.—Double Cylindrical Drums, 394; Single Cylindrical Drums, 394; Koepe System, 395; Whiting System, 395; Problems in Hoisting, 396; Balancing a Conical Drum, 396; Horsepower of an Engine for Hoisting, 396; Load That a Given Pair of Engines Will Start, 396; Approximate Period of Winding on a Cylindrical Drum, 397; Head-Frames, 397; Head-Sheaves, 397; Guides and Conductors, 398; Safety Catches, 398; Detaching Hooks, 398.
- HAULAGE.—Gravity Planes, 398; Number of Cars in a Trip on a Self-Acting Incline, 399; Engine Planes, 399; Size of Engines Required for Engine-Plane Haulage, 399; Horsepower of an Engine to Hoist a Given Load Up an Incline, 400; Rope Haulage, 400; Tail-Rope System, 401; Friction Pull on an Endless-Rope Haulage, 402; Inclined Roads, 402; Motor Haulage, 402; Locomotive Haulage, 402; Inclined Roads, 402; Motor Haulage, 402; Locomotive Haulage, 402; Compressed-Air Haulage, 403; Tractive Efforts of Compressed-Air Locomotives, 404; Electric Haulage, 406; Speed of Haulage, 405; Cost of Haulage, 409; Mine Roads and Tracks, 410; Grade, 410; Rails, 411; Gauge, 411; Curves, 411; To Bend Rails to Proper Arc for Any Radius, 412; Rail Elevation, 412; Rollers, 412; Switches, 413; Turnouts, 413; Slope Bottoms, 413; Tracks for Bottom of Shafts, 416; Surface Tracks for Slopes and Shafts, 417.
- ORE DRESSING AND THE PREPARATION OF COAL. Crushing Machinery, 418; tobject of Crushing, 418; Selection of a Crusher, 418; Jaw Crushers, 419; Dake Crusher, 419; Dodge Crusher, 419; Roll-Jaw Crushers, 420; Gyratory Crushers, 420; Rolls, 421; Cracking Rolls, 421; Corrugated Rolls, 422; Disintegrating Rolls and Pulverizers, 423; Hammers, 423; Crushing Rolls, 423; Amount Crushed, 424; Speeds, 424; Speed of Rolls, 425; Crushing Mills, 426; Roller Mills, 426; Ball Mills, 427; Gravity Stamps, 427; Order of Drop, 428; Speed of Stamps, 429; Shoes and Dies, 429; Life of the Shoes and Dies, 429; Cams, Stamp Heads, and Stems, 429; Tappets, 429; Battery Water, 430; Duty of Stamps, 430; Horsepower of Stamps, 430; Cost of Stamping, 430; Pneumatic Stamps, 430; Power Stamps, 431; Steam Stamp, 431; Miscellaneous Forms of Crushers, 431.
- Sizing and Classifying Apparatus.—Stationary, Screens, Grizzlies, Head-Bars, or Platform Bars, 431; Adjustable Bars, 432; Shaking Screens, 452; Revolving Screens, or Trommels, 433; Speed, 434; Duty of Anthracite Screens, 434; Revolving Screen Mesh for Anthracite, 434; Hydraulic Classifiers, 434; Spitzkasten, 435; Spitzlutten, 435; Calumet

Classifier, 435; Settling Boxes, 435; Jeffrey-Robinson Coal Washer, 436; Log Washer, 436; Scaife Trough Washer, 437; Jigs, 437; Stationary Screen Jigs, 437; Theory of Jigging, 439; Equal Settling Particles, 439; Interstital Currents, 439; Acceleration, 440; Suction, 440; Removal of Sulphur From Coal, 441; Preparation of Anthracite, 442.

- HANDLING OF MATERIAL.—Anthracite Coal, 443; Bituminous Coal, 443; Ore, Rock, Etc., 443; Flumes and Launders, 443; Horizontal Pressure Exerted Against Vertical Retaining Walls, 444; Horsepowers for Coal Conveyers, 445; Weights and Capacities of Standard Steel Buckets, 446; Elevating Capacities of Malleable Iron Buckets, 446; Conveying Capacities of Flight at 100 Feet per Minute, 446; Cost of Unloading Coal, 447; Briqueting, 448; Volume of a Ton of Different Sizes of Coal, 449.
- TREATMENT OF INJURED PERSONS.—Loss of Blood, 449; To Transport a Wounded Person Comfortably, 450; Bleeding From Scalp Wounds, 451; Treatment of Persons Overcome by Gas, 451.
- TABLES.—Coal Dealers' Table, Giving Cost of Any Number of Pounds at Given Price Per Ton, 452; Natural Sines and Cosines, 453; Natural Stangents and Cotangents, 464; Logarithms of Numbers, 473; Logarithms of Trigonometric Functions, Sines, Cosines, Tangents, Cotangents, 492; Latitudes and Departures (Traverse Table), 537; Squares, Cubes, Square and Cube Roots, Circumferences, Areas, and Reciprocals, From 1 to 1,000, 545; Diameters, Circumferences, and Areas, & to 100, 561.

GLOSSARY OF MINING TERMS. -565.

Acres Same

COAL AND METAL MINERS'

POCKETBOOK.

WEIGHTS AND MEASURES.

THE METRIC SYSTEM.

Since the metric system is the adopted system in many countries, and as it is almost universally used in connection with scientific work, a brief description of it is here given as preliminary to the following tables of weights and measures.

The metric system has three principal units:

1. The meter, or unit of length, supposed to be the one ten-millionth part of the distance from the equator to the pole on the meridian of longitude passing through the city of Paris. Its actual value is 39.370432 in., the standard authorized by the United States Government being 39.37 in. According

to this standard, 1 yd. = $\frac{3,600}{3,937}$ meter.

2. The gram, or unit of ucight, is the weight of a cubic centimeter of distilled water at 4° centigrade and 776 millimeters of atmospheric measure. The kilogram (Kg.) = 1,000 grams = 2.2046 lb., is the ordinary unit of weight corresponding to the English pound. According to the United States Government regulations 1 lb. avoirdurois = — 1 kilogram.

ernment regulations, 1 lb. avoirdupois = $\frac{1}{2.2046}$ kilogram.

3. The liter, or unit of liquid volume, is the volume of 1,000 cubic centimeters of distilled water at 4° centigrade and 776 millimeters pressure.

Multiples of these units are obtained by prefixing to the names of the printed units the Greek words deka (10), hekto (100), kito (1,000). The submultiples or divisions are obtained by prefixing the Latin words dect ($\frac{1}{140}$), and milli ($\frac{1}{1400}$). The abbreviations of these several units as given in the following tables are those commonly used. The kilogram-meter is the work done in raising 1 kg. through a height of 1 m., and equals 7.233 ft.-lb. One metric horsepower (force de cheval or cheval vapeur) equals .98633 English horsepower.

TROY WEIGHT.

24 grains = 1 pennyweight.
20 pennyweights = 1 ounce = 480 grains.
12 ounces = 1 pound = 5,760 grains = 240 pennyweights.
In troy, apothecaries', and avoirdupois weights, the grains are the same.

APOTHECARIES' WEIGHT.

20 grains = 1 scruple. 3 scruples = 1 dram = 60 grains. 8 drams = 1 ounce = 480 grains = 24 scruples. 12 ounces = 1 pound = 5,760 grains = 288 scruples = 96 drams.

AVOIRDUPOIS WEIGHT.

27.34375 grains	=	1 dram.					
16 drams	=	1 ounce		=	= 4371	grains.	
16 ounces		1 pound			= 7,000	grains = 256	drams.
28 pounds	=	1 quarte	r	-	= 448	ounces.	
4 quarters	_	1 hundr	edweig	ght =	= 112	pounds.	
20 hundredweight	==	1 ton	_	=	= 2,240	pounds.	
•		1 stone		=	= 14	pounds.	
		1 quinta	1	=	= 100	pounds.	
		1 " short	ton"	=	= 2.000	pounds.	
		1 "long	ton'	=	= 2.240	pounds.	
1 ounce troy or apo				714		pois ounces.	
1 pound troy or apo	the	caries' :	= .822	286	avoirdu	ipois pound.	
l ounce avoirdupoi			= .91	1458		apothecaries	ounce.
1 pound avoirdupoi	8		= 1.213	528	troy or	apothecaries	' pounds.

AETRIC WEIGHT.

		METRIC WEIGHT.			
10 milligrams (mg.)	==	1 centigram (cg.)	_	.15432	grain.
10 centigrams	=	1 decigram (dg.)	=	1.5432	grains.
10 decigrams		1 gram (g.)	=		grains.
10 grams	=	1 decagram (Dg.)	=		lb. avoir.
10 decagrams	=	1 hectogram (Hg.)	=		lb. avoir.
10 hectograms	=	1 kilogram (Kg.)	=	2.2046	lb. avoir.
10 kilograms	=	1 myriagram (Mg.)	==		lb. avoir.
10 myriagrams	=	1 quintal (Q.)	=		lb. avoir.
10 quintals	=	1 tonneau, millier, or tonne	==	2,204	lb. avoir.

MEASURES OF LENGTH.

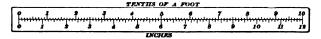
AMERICAN AND BRITISH.

```
12 inches
               = 1 foot.
                                    36 in.
3 feet
               = 1 yard
6 feet
               = 1 fathom =
                                    2 yd.
11 fath.
                                                      72 in.
                                                = 22 \text{ yd.} = 792 \text{ in.}
= 220 yd. = 660 ft.
66 feet
               = 1 chain * =
10 chains
              = 1 furlong = 110 fath.
                                                                               == 7.620 in.
                               = 80 \text{ chains} = 880 \text{ fath.} = 1.760 \text{ yd.} = 5.280 \text{ ft.}
8 \text{ furlongs} = 1 \text{ mile}
                 A nautical mile, or knot = 1.15136 statute miles.
                                                                                     [63,360 in.
                              A league = 3 nautical miles.
```

*The chain of 66 ft. is practically obsolete. Chains of 50 or 100 ft. are now used exclusively by American surveyors.

To Reduce Inches to Decimals of a Foot.—Divide the number of inches by 12. Thus, 7 in. = $7 \div 12$, or .5833 ft. To reduce fractions of inches to decimals of a foot, divide the fraction by 12, and then divide the numerator of the quotient by the denominator. Thus, $\frac{1}{8}$ in. = $\frac{1}{8} \div 12 = \frac{3}{88}$. $\frac{3}{88}$ = .0313 ft.

The annexed scale shows on one side, proportionately reduced, a scale of tenths. On the other, a scale of twelfths, corresponding to inches. Treduce inches to decimal parts of a foot, find the number of inches and



fractional parts thereof on the side marked "inches." Opposite, on the scale of tenths, will be found the decimal part of a foot. Thus, if we want to find the decimal part of a foot represented by 7½ inches, we find the mark corresponding to 7½ inches on the side marked "inches." Opposite this mark we read 6 tenths, 2 hundredths, and 5 thousandths; or, expressed decimally, 625.

DECIMALS OF A FOOT FOR EACH 1-32 OF AN INCH.

Inch.	0"	1′′	2''	3′′	4′′	5′′	6′′	7''	8′′	9"	10"	11"
ō	0		.1667	.2500	.3333	.4167	.5000	.5833	.6667	.7500	.8333	
3,3		.0859		.2526							.8359	
बुड़े दुंख बुड़े	.0052	.0885	.1719	.2552	.3385	.4219	.5052	.5885	.6719	.7552	.8385	.9219
युंख	.0078	.0911	.1745	.2578	.3411	.4245	.5078	.0911	.6745	.1318	.8411	.9245
2,2 2,3 2,4	.0104		.1771	.2604	.3437	.4271	.5104	.5937	.6771	.7604	.8437	
aŞ≢ ,	.0130	.0964	.1797	.2630	.3464	.4297	.5130	.0964	.6797	.7630	.8464	
- Çe		.0990		.2656					.6823		.8490	
2,2	.0182				.3516				.6849		.8516	
<u>.</u>		.1042		.2708	.3542	.43/0	.5208	.0042	.6873	.7708	.8042	.9375
37	.0234			2/34	.3568	.4401	5000	.0000	.0901	.1134	.8008	.9401
Ĭ.			.1927	.2760	.3594 .3620	4427	.0200	.0094			.8620	
3,1			.1953			.4479			.6953			
1									.6979		.8646	
ŷ		.1172		.2839	3600	$.4505 \\ .4531$	5005		.7005		.8672	
11	.0391	.1198		.2865	9704	.4557	5901	.6198	.7031		.8698	
3,5	.0391			.2891		.4583		.6250	.7057 .7083			.9557 .9583
3) 1	.0443			.2913		.4609		.6276		.7943	.8750	
33	.0469		.2135	.2969		.4635		.6302			.8802	
15		.1328	.2161		3828	1661	5405	.6328				
3,3		.1354				.4688		.6354		.7995 .8021	.8854	.9688
		.1380		.3047						.8047		
11	.0573	.1406		.3073	3006	.4714	5579	.6406		.8073		
15	.0599	.1432	.2266	.3099		.4766		.6432		.8099		.9766
37	.0625	.1458		.3125		.4792		.6458			.8958	.9792
25	.0651	.1484		.3151		.4818		.6484			8984	
9 8 1 8 1 8 2 7	.0677	.1510	.2344	.3177		.4844		.6510	.7344		.9010	
17	.0703	.1536	.2370	.3203		.4870		.6536		8203	.9036	.9870
7	.0729	.1562	.2396		.4062			.65621			9062	
2.2	.0755	.1589	.2422		.4089			.6589		.8255		
33	.0781	.1615	.2448	.3281	.4115	4948	.5781			.8281		
	.0807	.1641	.2474		.4141							
37												

METRIC SYSTEM.

10 millimeters (centimeter (cm.)	572	.3937079	inch.
10 centimeters	 ==	1	decimeter (dm.)	-12	3.937079	inches.
10 decimeters		1	meter (m.)	5.13	3.2808992	feet.
10 meters	-=	1	decameter (Dm.)	1.3	10.9363	yards.
10 decameters			hectometer (Hm.)			
10 hectometers			kilometer (Km.)			
10 kilometers	=	1	myriameter(Mm.)	2.3	6.213824	miles.

RUSSIAN.

12 inches = 1 foot = 1 American foot. 7 feet = 1 sachine, or sagene. 500 sachine = 1 verst = 3,500 feet.

PRUSSIAN, DANISH, AND NORWEGIAN.

 $\begin{array}{lll} \mbox{12 inches} = 1 \mbox{ foot} = 1.02972 \mbox{ American feet.} \\ \mbox{12 feet} & = 1 \mbox{ ruth} = 12.35664 \mbox{ American feet.} \\ \mbox{2,000 ruths} & = 1 \mbox{ mile} = 4.68+ \mbox{ American miles.} \end{array}$

AUSTRIAN.

```
12 inches = 1 foot = 1.03713 American feet.
6 feet = 1 klafter.
4.000 klafters = 1 mile = 4.71+ American miles.
```

SWEDISH.

CHINESE.

 $\begin{array}{lll} 1~chih &=& 1.054~American~feet.\\ 10~chih &=&1~chang =& 10.54~American~feet.\\ 180~chang =&1~li &=&1,897~American~feet. \end{array}$

MEASURES OF AREA.

AMERICAN AND BRITISH.

144 sq. inches = 1 square foot. 9 sq. feet = 1 square yard = 1,296 sq. in. 304 sq. yards = 1 perch = 2724 sq. ft. 40 perches = 1 rood = 1,210 sq. yd. = 10,890 sq. ft.

4 roods = 1 acre = 160 perches = 4,840 sq. yd. = 43,560 sq. ft. 640 acres = 1 square mile.

TABLE FOR REDUCING SQUARE FEET TO ACRES.

Square Feet.	Acres.	Square Feet.	Acres.	Square Feet.	Acres.	Square Feet.	Acres.
100,000,000	2,295.684						
90,000,000	2,066.116	900,000	20.661	9,000	.207	90	.0021
80,000,000	1,836.547	800,000	18.365	8,000	.184	l 80	.0018
70,000,000	1,606.979	700,000	16.070	7,000	.161	70	.0016
60,000,000	1.377.410	600,000	13.774	6,000	.138	l 60	.0014
50,000,000	1,147,842	500,000	11.478	5,000	.115	50	.0011
40,000,000	918,274	400,000	9.183	4,000	.092	40	.0009
30,000,000	688,705	300,000	6.887	3,000	.069	30	.0007
20,000,000	459,137	200,000	4.591	2,000	.046	20	.0005
10,000,000	229.568	100,000	2.296	1,000	.023	10	.0002
9,000,000	206.612	90.000	2.066	900	.021	9	.00021
8,000,000	183,655	80,000	1.836	800	.018	8	.00018
7.000,000	160.698	70,000	1.607	700	.016	l 7	.00016
6,000,000	137.741	60,000	1.377	600	.014	16	.00014
5,000,000	114.784	50,000	1.148	500	.011	5	.00011
4.000,000	91.827	40,000	.918	400	.009	4	.00009
3,000,000	68.870	30,000	.689	300	.007	ŝ	.00007
2,000,000	45.914	20,000	.459	200	.005	Ž	.00005
1.000,000	22.957	10,000	.230	100	.0023	2	.00002

METRIC SYSTEM.

1 square millimeter (sq. mm.)	=	.001550 sq. in.
1 square centimeter (sq. cm.)	=	.155003 sq. in.
1 square decimeter (sq. dm.)		
1 square meter, or centare (m. or sq. m.)	=	10.764101 sq. ft.
1 square decameter, or are (sq. Dm.)	==	.024711 acre.
1 hectare (ha.)	=	2.47110 acres.
1 square kilometer (sq. Km.)		247.110 acres.
1 square myriameter (sq. Mm.)	_	38.61090 sq.mi.

MEASURES OF VOLUME.

AMERICAN AND BRITISH.

1,728 cubic inches = 1 cubic foot.

A cord of wood = 128 cu. ft., or a pile of wood 8 ft. long, 4 ft. wide, and 4ft. high = 1 cord. A perch of masonry contains 24f cu. ft.; but in practice

it is taken as 25 cu. ft. A ton (2,240 lb.) of Pennsylvania anthracite, when broken for domestic use, occupies about 42 cu. ft. of space; bituminous coal, about 46 cu. ft.; and coke, about 88 cu. ft. A bushel of coal is 80 lb. in Kentucky, Illinois, and Missouri, 76 lb. in Pennsylvania, and 70 lb. in Indiana.

METRIC SYSTEM.

```
1 milliliter, or cu. centimeter (cc. or cm.3)
                                                          .0610254 cu. in.
1 centiliter (cl.)
1 deciliter (dl. or dl.)
                                                          .610254 cu. in.
                                                    _
                                                         6.10254
                                                   -
                                                                   cu. in.
                                                   = 61.0254
1 liter, or cu. decimeter (l.)
                                                                   cu. in.
1 decaliter, or centistere (Dl. or dal.)
                                                   --
                                                         .353156 cu. ft.
1 hectoliter, or decistere (Hl.)
                                                         3.53156
                                                   =
                                                                  cu. ft.
1 kiloliter, or cu. meter, or stere (Kl. or cm.3) = 35.3156
                                                                  cu. ft.
1 myrialiter, or decastere (Ml.)
                                                   = 353.156
                                                                  cu. ft.
```

LIQUID MEASURE (U. S.).

```
= 16 liquid oz. = 28.

= 8 gills = 57.

= 82 gills = 8 pints = 231

= 7,276\(\frac{1}{2}\) cu. in. = 4.21
  4 gills
                               = 1 pint
                                                                                                          = 28.876 cu. in,
= 57.75 cu. in.
                               = 1 quart
= 1 gallon
= 1 barrel
 2 pints
4 quarts
                                                                                                                               cu. in.
311 gamon.
63 gallons = 1 nob.
2 hogsheads = 1 pipe.
= 1 tun.
314 gallons
                                                                                                                              cu. ft.
                               = 1 hogshead.
```

A box 194 in. on each side contains 1 barrel.

DRY MEASURE (U. S.).

```
2 \text{ pints} = 1 \text{ quart} = 67.2006 \text{ cu. in.} = 1.16365 \text{ liquid qt.} 
4 \text{ quarts} = 1 \text{ gallon} = 268.8025 \text{ cu. in.} = 1.16365 \text{ liquid gal.} 
2 gallons = 1 peck = 8 quarts
4 pecks = 1 bushel = 64 pints
                                                      8 \text{ quarts} = 537.6050 \text{ cu. in.}
                                                                                    = 32 \text{ quarts} = 8 \text{ gal.} = 2,150.42 \text{ cu. in.}
```

BRITISH IMPERIAL MEASURE, BOTH LIQUID AND DRY.

```
4 gills
            = 1 pint
                                      34.6592 cu. in.
2 pints = 1 quart =
                                      69.3185 cu. in.
                                     277.274 cu. in.
4 quarts = 1 gallon =
8 \text{ quarts} = 1 \text{ peck} = 554.548 \text{ cu. in.}

4 \text{ pecks} = 1 \text{ bushel} = 2,218.192 \text{ cu. in.}
                                     554.548 cu. in.
```

The standard U.S. bushel is the Winchester bushel, which is in cylinder form, 181 inches diameter and 8 inches deep, and contains 2,150.42 cubic inches.

The British Imperial bushel is based on the Imperial gallon and con-

tains 8 such gallons, or 2,218.192 cubic inches = 1.283; cubic feet.

Capacity of a cylinder in U. S. gallons = square of diameter in inches height in inches × .0034 (accurate within 1 part in 100,000).
 Capacity of a cylinder in U. S. bushels = square of diameter in inches × height in inches × .003652.

CONTENTS OF CYLINDERS OR PIPES FOR 1 FOOT IN LENGTH.

The contents of pipes or cylinders in gallons or pounds are to each other as the squares of their diameters. Thus, a pipe 9 ft. in diameter will contain 9 times as much as a 3' pipe, or 4 times as much as a 44' pipe.

DIAMETERS IN INCHES.

Di a m. in Inches.	Diameter in Decimals of a Foot.	Gallons of 231 Cu. In. (U. S. Stand- ard.)	Weight of Water in Lb. in 1 Ft. of Length.	Diam. in Inches.	Diameter in Decimals of a Foot.	Gallons of 231 Cu. In. (U. S. Stand- ard.)	Weight of Water in Lb in 1 Ft. of Length.
14	.0208	.0025	.02122	5	.4167	1.020	8.488
ł	.0417	.0102	.08488	5ŧ	.4583	1.234	10.270
4	.0625	.0230	.19098	6	.5000	1.469	12,223
1	.0833	.0408	.33952	61	.5417	1.724	14.345
14	.1042	.0638	.53050	7	.5833	1.999	16.636
11	.1250	.0918	.76392	71	.6250	2.295	19.098
1#	.1458	.1249	1.0398	8 .	.6667	2.611	21.729
2	.1667	.1632	1.3581	81	.7083	2.948	24.530
21	.1875	.2066	1.7188	9	.7500	3.305	27.501
2	.2083	.2550	2.1220	91	.7917	3,682	30.641
23	.2292	.3085	2.5676	10	.8333	4.080	33.952
3	.2500	.3672	3.0557	101	.8750	4.498	37.432
31	.2917	.4998	4.1591	11	.9167	4.937	41.082
4	.3333	.6528	5.4323	114	.9583	5.396	44.901
41	.3750	.8263	6.8750	12	1.0000	5.875	48.891

DIAMETERS IN FEET.

11	1.25	9.18	76.392	10	10.00	587.6	4,889.12
1	1.50	13.22	110.00	101	10.50	647.7	5,404.24
1‡	1.75	17.99	149.73	11	11.00	710.9	5,915.84
2	2.00	23.50	195.56	111	11.50	777.0	6,485.72
21	2.25	29.74	247.51	12		846.1	7.040.00
$2\frac{1}{2}$	2.50	36.72	305.57	13		992.8	8,710.00
2₹	2.75	44.43	369.74	14		1,152.0	10,096.00
3	3.00	52.88	440.00	15		1,322.0	11,000.50
31	3.25	65.28	544.37	16		1,504.0	12,516.00
31	3.50	71.97	631.00	17		1,698.0	14,166.00
3	3.75	82.62	687.53	18		1,904.0	15,841.00
4	4.00	94.0	782.24	19		2,121.0	17,691.00
41	4.25	106.1	885.40	20		2,350.0	19,556,50
41	4.50	119.0	990.04	21		2,591.0	21,617.00
43	4.75	132.5	1.105.71	22		2,844.0	23,663.00
5	5.00	146.9	1,222.28	23		3,108.0	25,943.00
$5\frac{1}{4}$	5.25	161.9	1,351.06	24		3,384.0	28,160.00
5 į	5.50	177.7	1,478.96	25		3,672.0	30,557.00
5₹	5.75	194.3	1,621.43	26		3,971.0	34,840.00
6	6.00	211.5	1,760.00	27		4,283.0	35,641.00
61	6.25	229.5	1,915.18	28		4,606.0	40,384.00
6 1	6.50	248.2	2,177.48	29		4,941.0	41,117.00
6₹	6.75	267.7	2,233.96	30		5,288.0	44,002.00
7	7.00	287.9	2,524.00	31		5,646.0	46,984.00
71	7.50	330.5	2,750.12	32		6.017.0	50,064.00
8	8.00	376.0	3,128.96	33		6,398.0	53,242.00
81	8.50	424.5	3,541.60	34		6,792.0	56,664.00
9	9.00	475.9	3,960.16	35		7.197.0	59,891.50
91	9.50	530.2	4,422.84	36		7,614.0	63,364.00

MEXICAN, CENTRAL AMERICAN, AND SOUTH AMERICAN WEIGHTS AND MEASURES.

The following table gives weights and measures in commercial use in Mexico and the republics of Central and South America, and their equivalents in the United States. Published by the Bureau of the American Republics.

Denomination.	Where Used.	U.S. Equivalents.
Arobe	Paraguay	25 pounds.
Arroba (dry)	Argentine Republic	25.3175 pounds.
Arroba (dry)	Brazil	32.38 pounds.
Arroba (dry)	Cuba	25.3664 pounds.
Arroba (dry)	Venezuela	25.4024 pounds.
Arroba (liquid)	Cuba and Venezuela	4.263 gallons.
Barril	Argentine Republic and Mexico	20.0787 gallons.
Carga	Mexico and Salvador	300 pounds.
Centavo	Central America	4.2631 gallons.
Cuadra	Argentine Republic	4.2 acres.
Cuadra	Paraguay	78.9 yards.
Cuadra (square)	Paraguay	8.077 square feet
Cuadra	Uruguay	2 acres (nearly).
Fanega (dry)	Central America	1.5745 bushels.
Fanega (dry)	Chile	2.575 bushels.
Fanega (dry)	Cuba	1.599 bushels.
Fanega (dry)	Mexico	1.54728 bushels.
Fanega (dry)	Uruguay (double)	7.776 bushels.
Fanega (dry)	Uruguay (single)	3.888 bushels.
Fanega (dry)	Venezuela	1.599 bushels.
Frasco	Venezuela Argentine Republic	2.5096 quarts.
Frasco	Mexico	2.5 quarts.
League (land)	Paraguay	4.633 acres.
Libra	Argentine Republic	1.0127 pounds.
Libra	Central America	1.043 pounds.
Libra	Chile	1.014 pounds.
Libra	Cuba	1.0161 pounds.
Libra	Mexico	1.01465 pounds.
Libra	Peru	1.0143 pounds.
Libra	Uruguay	1.0143 pounds.
Libra	Venezuela	1.0161 pounds.
Livre	Guiana	1.0791 pounds.
Manzana	Costa Rica	1 acres.
Marc	Bolivia	.507 pound.
Pie	Argentine Republic	.9478 foot.
Quintal	Argentine Republic	101.42 pounds.
Quintal	Rrazil	130.06 pounds.
Quintal	BrazilChile, Mexico, and Peru	101.61 pounds.
Quintal	Paraguay	100 pounds.
Suerte	Urnoney	2.700 cuadras.
Vara	UruguayArgentine Republic	34.1208 inches.
Vara	Central America	38.874 inches.
Vara	Chile and Peru	33.367 inches.
Vara	Cuba	33.384 inches.
Vara	Mexico	33 inches.
VaraVara	Paraguay	34 inches.
Vara	Venezuela	33.384 inches.
vara	venezueia	30.384 Inches.

CONVERSION TABLES.

(United States Coast and Geodetic Survey.)

The method of using the following tables for converting United States weights and measures into metric weights and measures will be understood by the following example:

Find the number of kilometers in 125 miles. From column "Miles to Kilometers," 1 mile = 1.60935 kilometers, or 100 miles = 160.935 kilometers; 2 miles = 3.21869 kilometers, or 20 miles = 32.1869 kilometers; and 5 miles = 8.04674 kilometers. Hence, 125 miles = 160.935 + 32.1869 kilometers.

CUSTOMARY TO METRIC.

		Lini	EAR.				CAPA	CITY.	
	Inches to Millimeters.	Feet to Meters.	Yards to Meters.	Miles to Kilometers.		Fluid Dramsto Millimeters, or Cubic Centimeters.	Fluid Ounces to Millimeters.	Quarts to Liters.	Gallons to Liters.
1 2 3 4 5 6 7 8 9	25.4 50.8 76.2 101.6 127.0 152.4 177.8 203.2 228.6	0.304801 0.609601 0.914402 1.219202 1.524003 1.828804 2.133604 2.438405 2.743205	0.914402 1.828804 2.743205 3.657607 4.572009 5.486411 6.400813 7.315215 8.229616	1.60935 3.21869 4.82804 6.43739 8.04674 9.65608 11.26543 12.87478 14.48412	1 2 3 4 5 6 7 8 9	3.70 7.39 11.09 14.79 18.48 22.18 25.88 29.57 33.27	29.57 59.15 88.72 118.29 147.87 177.44 207.02 236.59 266.16	0.94636 1.89272 2.83908 3.78543 4.73179 5.67815 6.62451 7.57087 8.51723	3.78543 7.57087 11.35630 15.14174 18.92717 22.71261 26.49804 30.28348 34.06891
_		SQUA	RE.		Ī		WEIG	HT.	i
	Square Inches to Square Centimeters.	Square Feet to Square Decimeters.	Square Yards to Square Meters.	Acres to Hectares.		Grains to Milligrams.	Avoirdupois Ounces to Grams.	Avoirdupois Pounds to Kilograms.	Troy Ounces to Grams.
1 2 3 4 5 6 7 8 9	6.452 12.903 19.355 25.807 32.258 38.710 45.161 51.613 58.065	9.290 18.581 27.871 37.161 46.452 55.742 65.032 74.323 83.613	0.836 1.672 2.508 3.344 4.181 5.017 5.853 6.689 7.525	0.4047 0.8094 1.2141 1.6187 2.0234 2.4281 2.8328 3.2375 3.6422	1 2 3 4 5 6 7 8 9	64.7989 129.5978 194.3968 259.1957 323.9946 388.7935 453.5924 518.3914 583.1903	28.3495 56.6991 85.0486 113.3981 141.7476 170.0972 198.4467 226.7962 255.1457	0.45359 0.90719 1.36078 1.81437 2.26796 2.72156 3.17515 3.62874 4.08233	31.10348 62.20696 93.31044 124.41392 155.51740 186.62088 217.72437 248.82785 279.93133
		Cub	IC.				<u>' </u>		
	Cubic Inches to Cubic Centimeters.	Cubic Feet to Cubic Meters.	Cubic Yards to Cubic Meters.	Bushels to Hectoliters.		Gunter's		20.116	8 meters.
1 2 3 4 5 6 7 8 9	16.387 32.774 49.161 65.549 81.936 98.323 114.710 131.097 147.484	.02832 .05663 .08495 .11327 .14158 .16990 .19822 .22654 .25485	0.765 1.529 2.294 3.058 3.823 4.587 5.352 6.116 6.881	0.35239 0.70479 1.05718 1.40957 1.76196 2.11436 2.46675 2.81914 3.17154	1 1 1	avoir. pot	== mile == 801 meter	1.829 1,853.25 9.484 453.592	hectares. meters. meters. 0158 log. 4277 gram. ogram.

The method of using the following tables for converting metric weights and measures into United States weights and measures may be understood by the following are made:

by the following example: Find the number of yards in 86 meters.

From column "Meters to Yards," 8 meters = 8.748889 yards, or 80 meters = 87.48889 yards; and 6 meters = 6.561667 yards. Hence, 86 meters = 87.48889 + 6.561667 = 94.050557 yards.

METRIC TO CUSTOMARY.

_			M	ETRIC	T	O CUST	0	MAR	Y.				
_		LINE	AR.										
	Meters to Inches.	Meters to Feet.	Meters to Yards.	Kilometers to Miles.		Millimeters, or Cubic Centi- meters to Fluid Drams.		Centiliters to Fluid Ounces.	Liters to Quarts.		Decaliters to	Gallons.	Hectoliters to Bushels.
1 2 3 4 5 6 7 8 9	39.37 78.74 118.11 157.48 196.85 236.22 275.59 314.96 354.33	16.40417 19.68500	1.093611 2.187222 3.280833 4.374444 5.468056 6.561667 7.655278 8.748889 9.842500	0.62137 1.24274 1.86411 2.48548 3.10685 3.72822 4.34959 4.97096 5.59233	1 2 3 4 5 6 7 8 9	0.27 0.54 0.81 1.08 1.35 1.62 1.89 2.16 2.43	1 1 2 2	0.338 0.676 0.014 0.353 0.691 0.029 0.367 0.705 0.043	1.0567 2.113- 3.1700 4.2267 5.2834 6.3401 7.3968 8.4535 9.5101	7	2.64 5.28 7.92 10.56 13.20 15.85 18.49 21.13 23.77	34 51 68 85 02	2.8377 5.6755 8.5132 11.3510 14.1887 17.0265 19.8642 22.7019 25.5397
_	SQUARE.								WEIGH	T.			
	Square Centi- meters to Square Inches.	Square Meters to Square Feet.	Square Meters to Square Yards.	Hectares to Acres.		Milligrams to Grains.		Wilomeme to	Grains.	Hootomomo	to Ounces Avoir.		Kilograms to Pounds Avoir.
1 2 3 4 5 6 7 8	0.155 0.310 0.465 0.620 0.775 0.930 1.085 1.240 1.395	10.764 21.528 32.292 43.055 53.819 64.583 75.347 86.111 96.875	1.196 2.392 3.588 4.784 5.980 7.176 8.372 9.568 10.764	2.471 4.942 7.413 9.884 12.355 14.826 17.297 19.768 22.239	1 2 3 4 5 6 7 8 9	.01543 .03086 .04630 .06173 .07716 .09259 .10803 .12346 .13889		30, 46, 61, 77, 92, 108, 123.	432.36 864.71 297.07 729.43 161.78 594.14 026.49 458.85 891.21	10 14 11 22 24	3.5274 7.0548 0.5822 4.1096 7.6370 1.1644 4.6918 8.2192 1.7466		2.20462 4.40924 6.61387 8.81849 11.02311 13.22773 15.43236 17.63698 19.84160
_		CUB	IC.		l_		W	EIGH	T-(C	nt	inuea	l)	
	Cubic Centi- meters to Cubic Inches.	Cubic Decimeters to Cubic Inches.	Cubic Meters to Cubic Feet.	Cubic Meters to Cubic Yards.		Quintals to Pounds	Avoir.		Milliers, or Tonnes		Avoir.	Vilomomo	Allograms to Ounces Troy.
11 22 24 24 24 24 24 24 24 24 24 24 24 24	.0610 .1220 .1831 .2441 .3051 .3661 .4272 .4882 .5492	61.023 122.047 183.070 244.094 305.117 366.140 427.164 488.187 549.210	35.314 70.629 105.943 141.258 176.572 211.887 247.201 282.516 317.830	1.308 2.616 3.924 5.232 6.540 7.848 9.156 10.464 11.771	123456789	220. 440. 661. 881. 1,102. 1,322. 1,543. 1,763. 1,984.	.92 .85 .81 .77 .24		2,20 4,40 6,6 8,8 11,0 13,2 15,4 17,6 19,8	14. 19. 18. 18. 27. 32. 37.	6 2 9 5 1 7 4 0 6 6	1 1 1 2 2	32.1507 64.3015 96.4522 28.6030 60.7537 92.9044 25.0552 57.2059 89.3567

METRIC CONVERSION TABLE.

(Arranged by C. W. Hunt, New York.)

Millimeters \times .03937 = in. Millimeters \div 25.4 = in. Centimeters \times .3937 = in. Centimeters \div 2.54 = in. Meters × 39.37 = in. (Act Congress).

Meters × 32.81 = ft.

Meters × 1.094 = yd. Kilometers × .621 = miles. Kilometers ÷ 1.6093 = miles. Kilometers × 3,280.7 = ft. Square millimeters × .0155 = sq. in. Square millimeters \div 645.1 = sq. in. Square centimeters \times .155 = sq. in. Square centimeters $\div 6.451 = \text{sq. in.}$ Square meters \times 10.764 = sq. ft. Square kilometers \times 247.1 = acres. Hectare $\times 2.471 = acres$. Cubic centimeters \div 16.383 = cu. in. Cubic centimeters $\div 3.69 =$ fluid drams (U. S. P.). Cubic centimeters $\div 29.57 = \text{fluid oz.}$ (U. S. P.). Cubic meters \times 35.315 = cu. ft. Cubic meters \times 1.308 = cu. yd. Cubic meters \times 264.2 = gal. (231 cu. in.). Liters \times 61.022 = cu. in. (Act Congress). Liters \times 33.84 = fluid oz. (U. S. Phar.). Liters \times .2642 = gal. (231 cu. in.). Liters $\div 3.78 = \text{gal.} (231 \text{ cu. in.}).$ Liters \div 28.316 = cu. ft. Tonnes \times 1.102 = short tons. Tonnes \times .9839 = long tons.

Hectoliters \times 3.531 = cu. ft. Hectoliters \times 2.84 = bu. (2,150.42) cu. in.). $Hectoliters \times .131 = cu. yd.$ Hectoliters $\div 26.42 = \text{gal.}$ (231) cu. in.). $Grams \times 15.432 = gr.$ (Act Congress). $Grams \div 981 = dynes.$ Grams (water) \div 29.57 = fluid oz. $Grams \div 28.35 = oz.$ avoir. Grams per cu. cent. $\div 27.7 = 1b$. per cu. in. Joule \times .7373 = ft.-lb. Kilograms \times 2.2046 = lb. Kilograms \times 35.3 = oz. avoir. Kilograms \div 1,102.3 = ton (2,000 lb.). Kilogr. per sq. cent. \times 14.223 = 1b. per sq. in. Kilogram-meters \times 7.233 = ft.-lb Kilo per meter \times .672 - lb. per ft. Kilo per cu. meter $\times .026 = lb$. per cu. ft. Kilo per cheval \times 2.235 = lb. per H. P. Kilowatts \times 1.34 = H. P. Watts \div 746 = H. P. Watts \div .7373 = ft.-lb. per sec. Calorie \times 3.968 = B. T. U. Cheval vapeur \times .9863 = H. P. $(Centigrade \times 1.8) + 32 = degree F.$ Franc \times .193 = dollars. Gravity Paris = 980.94 centimeters per sec.

MONEY.

United States Currency.

10 mills = 1 cent. 10 cents = 1 dime. 10 dimes = 1 dollar. 10 dollars = 1 eagle. BRITISH MONEY.

4 farthings = 1 penny.
12 pence = 1 shilling.
20 shillings = 1 pound sterling.

21 shillings = 1 guinea.

STANDARD UNITED STATES COINS.

Gold.			Silver.			
Denomination.	Value.	Weight.	Denomination.	Value.	Weight.	
* Dollar Quarter eagle * Three-dollar piece Half eagle Eagle Double eagle	\$1.00 2.50 3.00 5.00 10.00 20.00	25.8 gr. 64.5 gr. 77.4 gr. 129.0 gr. 258.0 gr. 516.0 gr.	* Trade dollar Standard silver dollar Half dollar Quarter dollar Dime	\$1.00 1.00 .50 .25 .10	420.0 gr. 412.5 gr. 192.9 gr. 96.45 gr. 38.58 gr.	

[&]quot;Fineness" expresses the proportion of pure metal in 1,000 parts; thus, "900 fine" means that 900 of every 1,000 parts are pure metal. Fineness of

^{*} No longer coined.

U. S. coins = 900 pure metal, 100 alloy; alloy of gold coin is copper or copper and silver, but in no case shall silver exceed % of total alloy. Alloy of silver coin is copper.

Piece.	11.7	cight.	Contents.	
5-cent(nickel)	77.16	grains		
*3-cent	30	grains	75% copper, 25% nickel.	
*2-cent	66	grains		
1-cent (copper)	48	grains	95% copper, 5% tin and zinc.	
No longer coined.		J		

SPACE REQUIRED TO STORE U.S. COINS.

Description.	Amount.	How Put Up.	Space.
Gold coins Silver dollars Subsidiary silver	\$1,000.000 1,000,000 1,000,000	\$5,000 in 8-oz, duck bags 1,000 in 8-oz, duck bags 1,000 in 8-oz, duck bags	Nearly 17 cu. ft. 250 cu. ft. 150 cu. ft.
		ļ.	

A bag of standard silver dollars occupies a space 12 in. \times 9 in. \times 4 in.

TO CONVERT VALUE OF U. S. COINS INTO ENGLISH VALUES AND VICE VERSA. Rule.—Cents $(U,S.) \div 2.02771$, or $\times .49312$ English pence. Example.— 100 cents $\times .49312$ 49.312 pence = 4s. 1.312d. Rule.—English pence $\times 2.02771$ —cents (U,S.). Example.— 100d. $\times 2.02771$ = 202.771 cents $\cdot \$2.0277$.

Rule. — $\frac{Dollars}{4.8665}$ = pounds sterling.

EXAMPLE. $\frac{$100}{4.8665} = £20.548$, £.548 \times 240 = 131.5d. = 10s. 11.5d. **Rule.** $-Pounds \times 4.8665 = dollars (U.S.)$, Shillings \times 24.332 + = cents (U.S.).

VALUES OF FOREIGN COINS, U. S. TREASURY DEPT., JAN. 1, 1899.

Argentine, Argentine Re-	_	Doubloon, Central America	\$ 14.50
public	§ 4.824	Doubloon, Chile	3.650
Bolivar, Venezuela	.193	Doubloon, New Granada	15.34
Boliviano, Bolivia	.439	Doubloon, Spain and Mexico	15.65
Centen, Cuba	5.017	Drachma, Greece	.193
Colon, Costa Rica	.465	Ducat, Austria, Bohemia,	
Condor, Chile	7.300	Hamburg, Hanover	2.28
Condor, U.S. of Colombia and		Ducat, Denmark	1.11
Ecuador	9.647	Ducat, Sweden	2.20
Copeck, Russia	.0075	Escudo, Chile	1.825
Crown, Austria-Hungary	.203	Florin, Austria-Hungary	1.929
Crown, Denmark, Norway,		Florin, Hanover (gold)	1.66
and Sweden	.268	Florin, Hanover (silver)	.56
Crown, Germany	1.06	Florin, Holland, South Ger-	
Crown, Great Britain	1.13	many	.38
Crown, Sicily	.96	many Florin, Netherlands	.402
Crown, Spain (half pistole)	1.95	Florin, Prussia	.55
Dollar, Bolivia	.96	Florin, Silesia	.48
† Dollar, British Honduras,	ļ	Franc, Belgium, Bulgaria,	
British Possessions, N. A.	1	France, Italy, Roumania,	
(except Newfoundland),	1	Switzerland	.193
and Liberia	1.000	Gourde, Hayti	.965
Dollar, Chile, Peru, and		Groschen, Prussian Poland	.024
Ecuador	.93	Guinea, Great Britain	5.11
Dollar, Mexican (gold)	.983	Gulden, Baden	.40
Dollar, Mexican (silver)	.477	Imperial, Russia	7.92
Dollar, Newfoundland	1.014	Kran, Persia	.081
Dollar, U. S. of Colombia	.935	Kreutzer, Bavaria	.0067
		,	

[†]The British dollar has the same legal value as the Mexican dollar in Hongkong, the Straits Settlements, and Labuan.

VALUES OF FOREIGN COINS.—(Continued.)

Lira, Italy		Rupee, India	
Mark, Finland	.193	Shilling, Great Britain	.243
Mark, German Empire	.238	Sol, Peru	.439
Maximilian, Bavaria	3.30	Sou, France	.01
Milreis, Brazil	.546	Sovereign, Great Britain	4.8665
Milreis, Portugal	1.080	Sucre, Ecuador	.439
Mohur, India	7.105	(Amoy	.710
Napoleon, France	3.84	Canton	.708
Peseta, Spain	.193	Chefoo	.679
Peso, Argentine Republic	.965	Chin Kiang	.693
Peso, Chile	.365	Fuehau	.656
Peso, U. S. of Colombia	.439	Haikwan (Cus-	.000
Peso, Cuba	.926	toms)	.722
Peso, Guatemala, Honduras,	.920	Tool China Hankam	
	005	Tael, China { Hankow	.664
Nicaragua, Salvador	.365	Hongkong	<u> </u>
Peso, Uruguay	1.034	Niuchwang	.665
Piaster, Egypt	.049	Ningpo	.682
Piaster, Turkey	.044	Shanghai	.648
Piastre, Spain	1.04	Swatow	.655
Pistole, Rome	3.37	Takau	.714
Pistole, Spain	3.90	Tientsin	.688
Pound, Egypt	4.943	Toman, Persia	3.409
Pound Sterling, Great Britain	4.8665	Yen, Japan	.498
Ruble, Russia	.515	1 CII, 0 a pail	• 230
Itubic, Itussia	.010		

† The British dollar has the same legal value as the Mexican dollar in Hongkong, the Straits Settlements, and Labuan.

The cerat (a 24th part) is used to express the proportion of gold in an alloy; thus, gold 18 cerats fine is 15 pure. The carat is also a unit of weight for precious stones. Its value varies according to different authorities, but the international carat is 3.168 grains, or 206 milligrams.

DIAMOND WEIGHT (NYSTROM).

Carats.		Grains.	P	art	8.	Grains, Troy.
1	=					3.2
.25	=		=	16	=	.8
.015625	=					.05
.3125	=	12.5	==	20	=	1
15.5	=					1 ounce

TIMBER AND BOARD MEASURE.

TIMBER MEASURE.

Volume of Round Timber.—The volume in cubic feet equals the length multiplied by one-fourth the product of mean girth and diameter, all dimensions being in feet. If length is given in feet and girth and diameter in inches, divide by 144; if all dimensions are in inches, divide by 1,728.

Volume of Square Timber.—When all dimensions are in feet:

Rule.—Multiply the breadth by the depth and that product by the length, and the product will give the volume in cubic feet.

When either of the dimensions is in inches:

Bule.—Multiply as ghove and divide by 129.

Rule .- Multiply as above and divide by 12.

When any two of the dimensions are in inches:

Rule. - Multiply as before and divide by 144.

ROUND TIMBERS-TABLE OF & GIRTHS.

‡ Girths.	Area in	i Girths.	Area in	‡ Girths.	Area in
Inches.	Feet.	Inches.	Feet.	Inches.	Feet.
664 664 67 774 77 8 84 84 89 91 104 104 11 114 114	.250 .272 .294 .317 .340 .364 .364 .390 .417 .444 .472 .501 .531 .562 .594 .626 .659 .694 .730 .766 .803 .840 .878 .918 .959	124 124 124 13 134 134 134 14 141 142 15 154 16 164 167 177 174 174 18	1.04 1.08 1.12 1.27 1.21 1.26 1.31 1.36 1.41 1.46 1.51 1.66 1.72 1.77 1.83 1.89 1.94 2.00 2.12 2.18 2.23	19 19 20 20 21 21 21 21 21 21 21 21 21 21 21 21 21	2.50 2.64 2.77 2.91 3.06 3.20 3.36 3.51 3.67 3.83 4.06 4.34 4.16 4.34 4.51 4.69 5.25 5.44 5.64 5.84 6.25

Area corresponding to ½ girth (mean) in inches multiplied by length in feet equal solidity in feet and decimal parts.

BOARD MEASURE.

In measuring boards, they are assumed to be 1 inch in thickness. The number of feet, board measure (B. M.), in a given board or stick of timber, equals the length in feet multiplied by the breadth in feet multiplied by the thickness in inches.

Breadth.	Area of a	Breadth.	Area of a	Breadth.	Area of a
Inches.	Lineal Foot.	Inches.	Lineal Foot.	Inches.	Lineal Foot.
1 1 1 1 1 2 2 2 2 2 2 3 3 3 4 3 4 4 3 5 5 5 5 6 5 6 5 6 5 6 5 6 6 6 6 6 6 6	.021 .042 .063 .083 .104 .125 .146 .167 .188 .208 .229 .250 .271 .292 .313 .333	444 45 144 45 55 56 66 67 77 77 78	.354 .375 .396 .417 .438 .458 .479 .500 .521 .542 .563 .583 .604 .625 .646	8½ 8½ 8½ 9½ 9½ 10 10½ 10½ 10½ 11½ 11½ 11½ 11½	.688 .708 .729 .750 .771 .813 .833 .854 .875 .896 .917 .938 .958 .959

Area of a lineal foot multiplied by length in feet will give superficial contents in square feet.

MATHEMATICS.

BY EDWARD H. WILLIAMS, JR., E. M.

Professor of Mining Engineering and Geology at the Lehigh University.

GENERAL PRINCIPLES.

Quantity or magnitude is anything that can be increased or decreased, or that is capable of any sort of measurement or calculation, such as numbers, lines, space, time, motion, weight, force, power, heat, light, electricity, etc. We can measure a quantity by applying to it a portion of the same quantity called a unit. If the quantities are of different kinds, we cannot measure them by one another, but we can compare them or institute a calculation between them.

Mathematics treats of all kinds of quantity that can be numbered or measured. Arithmetic is that part that treats of numbering, and is called the science of numbers. Geometry is the science of measuring. These two are the foundation of all other parts of mathematics, and are called pure mathematics. We can also reason about numbers by substituting letters for numbers, and represent their relations by signs. This is called algebra, and it may be likened to a shorthand arithmetic. An extension of arithmetic to geometry, by which angles and triangles are subjected to numerical computation, is called trigonometry, and plane trigonometry treats of methods of computing plane angles and triangles, and embraces the investigations of the relations of angles in general, which is called angular analysis. Another extension of arithmetic to geometry, by which lines, areas, and volumes are computed, is called mensuration. Mensuration of large portions of the earth's surface, where the curvature of the same is taken into calculation, is called geodesy. If the portions are smaller and curvature is neglected, the science is called surveying, and mine surveying if confined to underground work.

COMMONLY USED MATHEMATICAL SIGNS AND ABBREVIATIONS.

+ means plus, or addition. - means minus, or subtraction. * means minus or minus. † means minus or plus. + means minus or plus. - means atio. :::: means proportion. 2:3::4:6 shows that 2 is to 5 as 4 is to 6. means equidity. means equivalency. means equivalency. means cube root, etc. 1/3 square root of 5. 2/4 7 squared. 8 scubed. a a / b, a + b. 15 + 16 = \frac{15}{16}. . therefore. greater than. less than. square. square. - square feet.	square inches. round. () [] { }, vincula, denoting that the numbers enclosed are to be taken together; as, (a + b) c = 4 + 3 × 5 = 35. degrees, are or thermometer. '' seconds or inches. 30° 40' 4'' 3'' 30 degrees 40 minutes 4 seconds. 4' 6'' 4' 6'' 4' 4 fect 6 inches. '' ''' 4', a ₂ , a ₄ , a ₆ , read a sub 1, a sub b, etc. a², a³ a squared, a cubed. a³ = b' a², a³ = 1/a¹. sin a = the sine of a. log angle. right angle. right angle. perpendicular to. sin sine. cos cosine.
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MATHEMATICAL SIGNS AND ABBREVIATIONS—(Continued).

I. H. P. indicated horsepower. B. H. P. brake horsepower. A. W. G. American wire gauge tan, or tang, tangent. indicated horsepower. sec secant. versin versed sine. cotangent. (Brown & Sharpe). cot B. W. G. Birmingham wire gauge. cosec cosecant. coversed sine. r. p. m., or rev. per min., revolutions covers pi, ratio of circumference of per minute.

A decimal point is a period (.) precircle to diameter 3.14159. acceleration due to gravity fixed to a number to show g that the number is less than = (32.16 ft. per sec.).R, r W, w H. P. unity (1); thus, $.2 = \frac{1}{100}$; $.35 = \frac{1}{100}$; $5.75 = 5\frac{1}{100}$, or $5\frac{1}{2}$. radius. weight. horsepower.

ARITHMETIC.

To Cast the Mines Out of a Number .- Add together the digits, and find how many nines are contained in their sum. Reject these nines and set down the remainder to the right of the number.

EXAMPLE.—Cast the nines out of 18,304. 18,304. 7. Ans. To Prove Addition.—Cast the nines out of each row of figures added, and out of their sum. Add together the remainder and cast the nines from its sum. If the remainder from this last process is equal to the remainder

Obtained from the sum of the numbers, the addition is correct. Example.—Prove this addition: 2.143,668 2

8,560,391 7. 10,703,959

Ans. To Prove Subtraction.—Add the remainder to the lesser number; their sum

should equal the larger number. To Prove Multiplication .- Cast the nines out of multiplicand and multiplier, and multiply the remainders together. Cast the nines out of the

product, and the remainder should equal the remainder obtained by casting the nines from the original product.

EXAMPLE.—Prove this multiplication: 3,542 × 6,196 = 21,946,232.

3.5 4 2 6,196

2. Ans. 2 1,9 4 6,2 3 2

To Prove Division.—Subtract the remainder, if there be any, from the dividend, and divide what remains by the quotient. If the new quotient

EXAMPLE.—Divide 31,046,835 by 56. 554,407 2. Ans. PROOF.—Take 43 from 31,046,835, and divide the remainder, 31,046,792, by 554,407. 56. Ans.

Rule.—To square any number containing the fraction 1, multiply the whole number by the next higher whole number, and add 1.

EXAMPLE.— $(8\frac{1}{8})^2 = 8 \times 9 + \frac{1}{4} = 72\frac{1}{4}$.

COMMON FRACTIONS.

A fraction is a part of a whole, as 1, 2, etc.

The numerator of a fraction is the number that tells how many parts of a whole are taken. Thus, 2 is the numerator of 3, as it shows that two of the

three parts into which the whole is divided are taken. The denominator of a fraction is the number that shows into how many parts the whole is divided. Thus, in the fraction 3, the 3 is the denominator.

A common denominator is a denominator common to two or more fractions. Thus, 1 and 2 have common denominators; and again, 12 is a common denominator for 1, 1, 1, and 1, as they each are respectively equal to 12, 12, 14, and 12.

To Add Common Fractions.—If of the same denominator, add together the

numerators only. Thus 18 + 18 + 18 = 18.

If they have different denominators, change them to fractions with common denominators, and proceed as before.

EXAMPLE.—What is the sum of $\frac{1}{3} + \frac{1}{4} + \frac{1}{8}$?

numerator, and the denominators for the denominator. Thus, $\frac{1}{2} \times \frac{1}{16} \times \frac{1}{3}$ $=\frac{1}{18}$, or $\frac{1}{18}$.

To Divide Common Fractions.—Invert the divisor, and multiply.

EXAMPLE.—Divide & by &.

 $\frac{s_0}{s_0} \times \frac{5}{2} = \frac{4}{15}$. Ans. To Reduce Compound Fractions to Simple Fractions.—Multiply the integer by the denominator of the fraction, add the numerator for the new numerator, and place it over the denominator.

EXAMPLE.—Reduce 53 to a simple fraction.

 $5 \times 3 + 2 = 17$, or the numerator, and the fraction is therefore $\sqrt{3}$. To Reduce Simple Fractions to Compound Fractions.—Divide the numerator by the denominator, and use the remainder as the numerator of the remaining fraction.

Example.—Reduce 4 to a compound fraction.

9)64(7 63 Compound fraction = 71. Ans.

80

To Reduce Common Fractions to Decimal Fractions.—Annex ciphers to the numerator, and divide by the denominator, and point off as many decimal places in the quotient as there are ciphers annexed.

EXAMPLE.—Reduce 18 to a decimal fraction.

16)9.0000(.5625 Ans. Note.—Ciphers annexed to a deci-80 mal do not increase its value. 1.13 is the same as 1.1300. Every cipher 100 96 placed between the first figure of a 4 0 decimal and the decimal point divides 32 the decimal by 10. Thus, $.13 \div 10 = .013$. 80

TABLE OF FRACTIONS REDUCED TO DECIMALS.

2 - 2 - 2 - 2 - 2 - 2 - 2 - 2 - 2 - 2 -	.015625 .08125 .046875 .0625 .078125 .09375 .109375 .125 .140625 .15625 .171875 .1875 .203125 .21875	7 & M.O. W. C. T. & C.	.265625 .28125 .296875 .3125 .328125 .34875 .359375 .379625 .40625 .421875 .4375 .4375 .484375	OBJUST COLOR DE CONTROL OBJUST COLOR	.515625 .53125 .546875 .5625 .578125 .59375 .609375 .625 .640625 .671875 .6875 .703125 .71875 .734375	CHACKS - 4-ADD VAN USE OF THE VAN US	.765625 .78125 .796875 .8125 .828125 .84375 .859375 .890625 .90625 .921875 .9375 .953126 .96875 .984375	

DECIMALS.

Decimal fractions have for their denominators 10 or a power of 10, but the denominator is usually omitted. Thus, $1 = \frac{1}{10}$; $0.01 = \frac{1}{100}$; .001 = 1000, etc.

To Add Decimals.-Place whole numbers under whole numbers, tenths under tenths, hundredths under hundredths, etc., and add, placing the decimal point in the sum directly under the points above. Thus.

.0075 .63 1.0617.9342 19.6317

To Subtract Decimals, -Arrange the figures as in addition, and proceed as in simple subtraction. Thus.

5.96978 3.28694 2.68284

To Multiply Decimals.—Proceed as in simple multiplication, pointing off as many decimal places in the result as there are decimal places in both multiplicand and multiplier.

4.67531 (5 decimal places.) .053 (3 decimal places.) 1402593 2337655 0.24779143 (8 decimal places.)

To Divide Decimals.—Proceed as in simple division, and point off as many decimal places in the quotient as the number of decimal places in the dividend exceeds those in the divisor.

EXAMPLE 1.—Divide 4.756 by 3.3.

33 70 EXAMPLE 2.—Divide .006 by 20. 20).0060(.0003 Ans.

Note.—It has been said before that algebra is a shorthand arithmetic. Before proceeding further with the various methods of arithmetic, the principles of algebra will be stated, and, after the subsequent examples are worked out by arithmetical rules, an example will be given of the algebraic method of doing the same. In every example, we have known quantities from which we seek to find certain unknown ones. While there is no way of indicating these in arithmetic, we can readily do so in algebra, by placing the first letters of the alphabet as representatives of the known quantities (as a, b, c), and the last letters (x, y, z) of the unknown ones. The signs in algebra are those just given for arithmetic. In addition to them, we can indicate multiplication by placing a period (.) between the quantities, as a, b(read a multiplied by b), or simply by placing the two letters together, as ab.

We can indicate division as in common fractions, $\frac{a}{b}$ being read a divided by b.

To illustrate algebraic symbols, let l denote the length, b the breadth, and b the height of a mine car. If it be desired to divide the height into the product of the length and breadth, it is expressed as follows:

lb

When two or more letters are placed together, without anything between them, it is understood that the quantities represented by those letters should be multiplied together. If l represents 8 and b represents 4, then 4 and 8 are multiplied together; thus, $4 \times 8 = 32$. If it be desired to divide the height into the sum of the length and breadth,

it is expressed thus:

The square of the length multiplied by the cube of the breadth, thus: $l^2 h^3$

The square root of the length divided by the cube root of the breadth, thus:

13/ b

The square root of the difference of the length and breadth divided by the height, thus:

$$\frac{\sqrt{l-b}}{h}$$

SIMPLE PROPORTION, OR SINGLE RULE OF THREE.

A proportion is an expression of equality between equal ratios; thus, the ratio of 10 to 5 = the ratio of 4 to 2, and is expressed thus:

There are four terms in proportion. The first and last are the extremes, and the second and third are the means.

Quantities are in proportion by alternation when antecedent is compared with antecedent and consequent with consequent. Thus, if 10:5::4:2,

then 10:4::5:2.

Quantities are in proportion by inversion when the antecedents are made consequents and the consequents antecedents. Thus, if 10:5::4:2, then 5:10::2:4.

In any proportion, the product of the means will equal the product of the

extremes. Thus, if 10:5::4:2, then $5\times 4=10\times 2$.

A mean proportional between two quantities equals the square root of their product. Thus, a mean proportional between 12 and 3 = the square root of

It 2×3 , or 6.

If the two means and one extreme of a proportion are given, we find the other extreme by dividing the product of the means by the given extreme. Thus, 10:5::4:(), then $(4 \times 5) \div 10 = 2$, and the proportion is 10:5::4:2. If the two extremes and one mean are given, we find the other mean by dividing the product of the extremes by the given mean. Thus, 10:()::4:2, then $(10 \times 2) \div 4 = 5$, and the proportion is 10:5::4:2.

EXAMPLE—If 6 men load 30 wagons of coal in a day, how many wagons

will 10 men load? (They will evidently load more, so the second term of the proportion must be greater than the first.) 6:10::30:(); then, $(10\times30)\div6=50$. Ans.

COMPOUND PROPORTION, OR DOUBLE RULE OF THREE.

PRINCIPLES.

1. The product of the simple ratios of the first couplet equals the product of the simple ratios of the second couplet. Thus,

2. The product of all the terms in the extremes equals the product of all the terms in the means. Thus, in

we have

$$4 \times 7 \times 10 \times 18 = 12 \times 14 \times 5 \times 6$$
.

3. Any term in either extreme equals the product of the means divided by the product of the other terms in the extremes. Thus, in the same proportion, we have

$$4 = \frac{5 \times 6 \times 12 \times 14}{7 \times 10 \times 18}.$$

Any term in either mean equals the product of the extremes divided by the product of the other terms in the means. Thus, in

we have

$$5 = (4 \times 7 \times 10 \times 18) \div (6 \times 12 \times 14).$$

Put the required quantity for the first term and the similar known quantity for the second term, and form ratios with each pair of similar quantities for the second couplet, as if the result depended on each pair and the second term.

Find the required term by dividing the product of the means by the product of the fourth terms.

EXAMPLE 1.—If 4 men can earn \$24 in 7 days, how much can 14 men earn in 12 days?

2 days?
The sum: \$24::
$${14:4 \atop 12:7}$$
; or, the sum = $\frac{24 \times 14 \times 12}{4 \times 7}$ = \$144. Ans.

EXAMPLE 2.—If 12 men in 35 days build a wall 140 rd, long, 6 ft, high, how

many men can, in 40 days, build a wall of the same thickness 144 rd. long, 5 ft. high?

$${ 40:35 \\ 140:144 \\ 6:5 } :: 12:() = {35 \times 144 \times 5 \times 12 \over 40 \times 140 \times 6} = 9. Ans.$$

INVOLUTION.

To Square a Number. - Multiply the number by itself. Thus, the square of $4 = 4 \times 4$, or 16.

To Cube a Number.-Multiply the square of the number by the number. Thus, the cube of $4 = 16 \times 4 = 64$.

To Find the Fourth Power of a Number.—Multiply the cube by the number. Thus, the fourth power of $4 = 64 \times 4 = 256$.

To Raise a Number to the Sixth Power.—Square its cube.

To Raise a Number to the Twelfth Power.—Square its sixth power.

(See logarithms for shorter method.)

EVOLUTION.

To Find the Square Root of a Number:

Rule .- I. Separate the given number into periods of two figures each, beginning at the units place.

II. Find the greatest number whose square is contained in the period on the lest: this will be the first figure in the root. Subtract the square of this figure from the period on the lest, and to the remainder annex the next period to form a dividend.

Divide this dividend, omitting the figure on the right, by double the part of the root already found, and annex the quotient to that part, and also to the divisor; then, multiply the divisor thus completed by the figure of the root last obtained, and subtract the product from the dividend.

W. If there are more periods to be brought down, continue the operation as before.

Example.-Find the square root of 874,225.

874225 (935 Ans. 81

OPERATION. $9 \times 2 = 18$. 18 into 64 goes 3 times, hence new divisor = 183. $93 \times 2 = 186$. 186 into

18 3 642 549 186 5 9325 9325

932 goes 5 times, hence new divisor = 1,865. (See logarithms for shorter method.)

The square root of a fraction is found by extracting the square root of the numerator and denominator separately. Thus, the square root of

When decimals occur, the number is pointed off into periods both right and left from the decimal point, and there will be as many decimal places in the root as there are periods to the right of the decimal point in the number.

EXAMPLE 1.-Find the square root of 874,225.

EXAMPLE 2.—Find the square 8'7 4.2 2'5 (2 9.5 6+ root of .00874225. .00'87'42'25 (.0935 49 474 81 441 18 3 642 58 5 3322 549 2925 186 5 9325 590 7 39750 9325 35442 4308+

To Find the Cube Root of a Number:

Rule .- I. Separate the given number into periods of three figures each, beginning at the units place.

II. Find the greatest number whose cube is contained in the period on the left; this will be the first figure in the root. Subtract the cube of this figure from the period on the left, and to the remainder annex the next period to form a dividend.

III. Divide this dividend by the partial divisor, which is 5 times the square of the root already found, considered as tens; the quotient is the second figure of the root.

IV. To the partial divisor add 5 times the product of the second figure of the root by the first considered as tens, also the square of the second figure; the result will be the complete divisor.

V. Multiply the complete divisor by the second figure of the root, and subtract

the product from the dividend.

1. If there are more periods to be brought down, proceed as before, using the part of the root already found, the same as the first figure in the previous process. EXAMPLE.—Find the cube root of 12,812,904.

OPERATION.

The cube root of a fraction is found by extracting the cube root of the numerator and denominator separately. Thus, the cube root of $\{i\} = \{i\}$. (See logarithms for shorter method.)

PERCENTAGE.

Percentage means by or on the hundred. Thus, $1\% = \frac{1}{100} = .01$, $3\% = \frac{1}{100}$

To Find the Percentage, Having the Rate and the Base.—Multiply the base by the rate expressed in hundredths. Thus 6% of 1,930 is found as follows: $1,930 \times .06 = 115.80$.

To Find the Amount, Having the Base and the Rate.—Multiply the base by 1 plus the rate. Thus, the amount of \$1,930 for one year at 6% is \$1,930 \times 1.06 **\$2,045.80.**

To Find the Base, Having the Rate and the Percentage.—Divide the percentage by the rate. Thus, if the rate is 64 and the percentage is 115.80, the base = $115.80 \div .06 = 1,930$.

To Find the Rate, Having the Percentage and the Base.—Divide the percentage by the base. Thus, if the percentage is 115.80 and the base 1,930, the rate equals $115.80 \div 1.930 = .06$, or 6%.

ARITHMETICAL PROGRESSION.

Quantities are said to be in arithmetical progression when they increase or decrease by a common difference. The following is an increasing series in arithmetical progression: 1, 3, 5, 7, 9, 11, 13. If the figures be read backward, 13, 11, 9, etc., it becomes a decreasing series. In the first series, the first term is 1; the last term 13; the number of terms 7; the common difference 2; and the sum of the terms 49.

In any arithmetical progression,

Let

f =first term; l =last, or nth term; d =common difference;

n = number of terms; and

s =their sum. The second term = f + (2-1)d = f + d; the fourth term = f + (4-1)d; and the nth term =

f+(n-1)d. (1)From equation (1) we obtain

f = l + (n - 1)d.(2)(4)

$$f = l + (n-1)d. (2) d = \frac{l-f}{n-1}. (4)$$

$$n = \frac{l-f}{d} + 1. (3) s = \frac{n}{2}(f+l). (5)$$

Substituting the value of l from (1).

$$s = \frac{n}{2}[2f + (n-1)d]. \tag{6}$$

EXAMPLE 1.—A company contracts to put down a bore hole at one dollar (\$1) per foot for the first 100 ft.; three dollars (\$3) per foot for the second 100

(\$1) per foot for the first 100 ft.; three dollars (\$3) per foot for the second 100 ft.; and two dollars (\$2) per foot additional for each successive 100 ft. The hole was 800 ft. deep. What was the cost? n=8; f=100; and d=2. Substitute these values in formula (6). $s=\frac{8}{4}[2\times100+(8-1)200]=\frac{86}{400}.$ Ans.

EXAMPLE 2.—If water flowing 10.12 gal. per min. be struck in a shaft 30 ft. below the surface, and the increase in flow be .02 gal. per ft. till the depth be 200 ft., and thence the flow decreases .02 gal. per ft. till the rock be dry, how deep was the shaft at the last point, and what was the total amount of water flowing into it ter minute?

flowing into it per minute? During the increase of flow, n = 170; f = 10.12; and d = .02. l [by formula (1)] = 10.12 + (170 - 1).02 = 13.50, or 13.50 gal. flow at a depth of 200 ft., and $s = \frac{17}{3} (2 \times 10.12 + (170 - 1).02] = 2,007.7$ gal. flowing in along the first

200 ft. in depth. During the decrease in flow f=18.50; d=.02, and l=.02.

$$n$$
 [formula (8)] = $\frac{l-f}{d}$ + 1, for a decreasing progression $n = -\frac{f-l}{d} + 1$.

Then, $-\frac{13.50 - .02}{.02} + 1 = 675$, the depth at which the rock will run dry,

and $s = \frac{a_1 a_2}{12} [2 \times .02 + (675 - 1) .02]$, or 4,563 gal., the amount of water that will flow in per minute along the last 675 ft. The total amount of water flowing in along the total depth of 875 ft. is 2,007.7 + 4,563, or 6,570.7 gal. Ans.

GEOMETRICAL PROGRESSION.

A series of quantities, in which each is derived from that which precedes

ratio; or, briefly, the ratio.

the ratio. f = first term; f = first term; l = last term, whose number from f is n; n = number of terms;

 $\tau = ratio;$

s = sum of terms.

$$s = \text{sum of terms.}$$

$$l = fr^{n-1}. \qquad (1) \qquad f = \frac{l}{r^{n-1}}. \qquad (4)$$

$$s = \frac{f(r^{n} - 1)}{r - 1}. \qquad (2) \qquad f = s - r (s - l). \qquad (5)$$

$$s = \frac{lr - f}{r - 1}. \qquad (3) \qquad r = \frac{s - f}{s - l}. \qquad (6)$$

$$s = \frac{f(r^m - 1)}{r - 1}$$
. (2) $f = s - r(s - l)$. (5)

$$s = \frac{lr - f}{r}. \tag{3} \qquad r = \frac{s - f}{s - l}.$$

EXAMPLE.—If a man should contract to sink a shaft to the base of the coal measures at the rate of $\frac{1}{2}$ cent for the first 50 ft.; $\frac{1}{2}$ cent for the second 50 ft.; $\frac{1}{2}$ cent for the third 50 ft.; and so on at the same rate, how much would be due if the shaft were 1,500 ft. deep?

 $f=\tau_0$; n=30; and r=2. Substituting in formula (1),

$$l = \frac{1}{16} \times (2^{29}) = 33,554,432, \text{ and } s \text{ [formula (3)]} = \frac{33.554,432 \times 2 - \frac{1}{16}}{2 - 1}$$

LOGARITHMS.

USE OF LOGARITHMS.

Logarithms are designed to diminish the labor of multiplication and division, by substituting in their stead addition and subtraction. A logarithm is the exponent of the power to which a fixed number, called the base, must be raised to produce a given number. The base of the common system is 10, and, as a logarithm is the exponent of the power to which the base must be raised in order to be equal to a given number, all numbers are to be regarded as powers of 10; hence,

```
10^{\circ} =
           1, we have logarithm of
                                         1 = 0.
10^{1} =
          10, we have logarithm of
                                        10 = 1.
102 =
         100, we have logarithm of
                                       100 = 2.
       1,000, we have logarithm of 1,000 = 3.
10^4 = 10,000, we have logarithm of 10,000 = 4.
```

The logarithms of numbers between 1 and 10 are less than unity, and are expressed as decimals. The logarithm of any number between 10 and 100 is more than 1 and less than 2, hence it is equal to 1 plus a decimal. Between 100 and 1,000, it is equal to 2 plus a decimal, etc.

The integral part of a logarithm is its characteristic, the decimal part is

its mantissa.

EXAMPLE.—The log of 67.7 is 1.830589, the characteristic of this logarithm is 1 and the mantissa is .830589.

The characteristic of a logarithm is always 1 less than the number of whole

figures expressing that number, and may be either negative or positive.

The characteristic of the logarithm of 7 is 0; of 17 is 1; of 717 is 2; etc.

The mantissa is the decimal portion of a logarithm, and is always considered

page of the table, along the column marked "No.," for the given number; opposite it will be found the logarithm with its characteristic.

To Find the Logarithm of Any Number Consisting of Three Figures.—Proceed in the same manner and find the decimal in the first column to the right of the number; prefix to this the characteristic 2. Thus, the logarithm of the number; prefix to this the characteristic 2. Thus, the logarithm of 327 is 2.514548. As the first two figures of the decimal are the same for several successive figures, they are only given where they change. Thus, the decimal part of the logarithm of 302 is 480007. The first two figures

remain the same up to 310, and are therefore to be supplied.
To find the Logarithm of Any Mumber of Four Figures.—Look in the column headed "No." for the first three figures, and then along the top of the page for the fourth figure. Down the column headed by the fourth figure, and opposite the first three, will be found the decimal part. To this prefix the

characteristic 3.

To Find the Logarithm of Any Number Containing More Than Four Figures. Place a decimal point after the fourth figure from the left, thus changing the number into an integer and a decimal. If the decimal part contains more than two figures, and its second figure is 5 or greater, add 1 to the first figure in the decimal. Find the mantissa of the first four figures and subtract from the next greater mantissa in the table. Under the heading "P.P." find a column headed by the difference first found; find in this column the number opposite the number corresponding to the first figure of the decimal, or the first figure increased by one, and add it to the mantissa already found for the first four figures of the given number.

EXAMPLE.—What is the logarithm of 234,567?

Placing a decimal point after the fourth figure from the left, we have 2.345.67. The mantissa of 2.345 is. 37014; the difference between .37014 and the next higher logarithm .37033 is 19. Add 1 to the first figure of the decimal 6, and in the column headed 19, under "P. P.," opposite 7, we find 18.3, which, added to the portion of the mantissa already found, .37014, gives .37027. characteristic is 5, hence the logarithm is 5.37027.

To Find the Logarithm of a Decimal Fraction.—Proceed according to previous rules, except in regard to the characteristic. Where the number consists of a whole number and a decimal, the characteristic is 1 less than the whole number. Where it is a simple decimal, or when there are no ciphers between the decimal point and the first numerator, the characteristic is negative, and is expressed by 1, with a minus sign over it. Where there is one cipher between the decimal point and first numerator, the characteristic is 2, with a minus sign over it. Where there are 2 ciphers, the characteristic is 3, with a minus sign over it. Thus:

The characteristic only is negative. The decimal part is positive.

To Find the Logarithm of a Vulgar Fraction.—Subtract the logarithm of the denominator from the logarithm of the numerator. The difference is the logarithm of the fraction.

EXAMPLE. - Find logarithm of 4.

$$\begin{array}{r}
\text{Log } 4 = 0.60206 \\
\text{Log } 10 = 1. \\
\hline
1.60206
\end{array}$$

 $\overline{1.60206}$ is the logarithm of .4.

To Find the Natural Number Corresponding to Any Logarithm.—Look in the column headed "0" for the first two figures of the decimal part; the other four figures are to be looked for in the same or in one of the nine following columns. If they are exactly found, the number must be made to correspond with the characteristic by pointing off decimals or annexing ciphers.

If the decimal portion cannot be found exactly, find the next lower logarithm, subtract it from the given logarithm, divide the difference by the difference between the next lower and the next higher logarithm, and annex

the quotient to the natural number found opposite the lower logarithm. To Multiply by the Use of Logarithms.—Add the logarithms of the factors together, the sum will be the logarithm of their product.

EXAMPLE.— $67.7 \times .677$.

$$\begin{array}{c} \textbf{Log 67.7} = \underline{1.830589} \\ \textbf{Log .677} = \underline{\overline{1.830589}} \\ \underline{\overline{1.661178}} \end{array}$$

1.661178 is the logarithm of 45.833.

To Divide by the Use of Logarithms.—Subtract the logarithm of the divisor from the logarithm of the dividend; the difference will be the logarithm of the quotient.

EXAMPLE.—Divide 67.7 by .0677.

$$\begin{array}{c} \text{Log } 67.7 = 1.830589 \\ \text{Log } .0677 = \overline{2}.830589 \\ 3.0\overline{0}000\overline{0} \\ 3 \text{ is the logarithm of } 1,000. \end{array}$$

To Square a Number by the Use of Logarithms.—Multiply the logarithm of the number by 2. The product will be the logarithm of the square of the number.

EXAMPLE.—Square .677.

$$Log.677 = \overline{1.830589}$$

1.661178 is the logarithm of .45833.

To Cube a Number.—Multiply the logarithm of the number by 3. The product will be the logarithm of the cube of the number.

To Reise a Number to Any Power, as 4th, 5th, 6th, or 7th, multiply the logarithm of the number by 4, 5, 6, or 7, and the results will be the logarithms of the 4th, 5th, 6th, or 7th powers, respectively. Thus, a number can readily be raised to any power required.

To Extract the Square, Cube, Fourth, Fifth, or Any Root of a Number.—Divide the logarithm of the number by the index of the root required, and the quotient will be the logarithm of the required root.

Thus, to find the square root of 625:

Logarithm of 625 = 2.795880. $2.795880 \div 2$ = 1.397940.1.397940 = logarithm of 25.

Therefore, the square root of 625 is 25.

To find the Cube, Fourth, or Any Root.—Proceed in the same way, using the index of the required root as a divisor.

To Divide a Logarithm Having a Negative Characteristic.—If the characteristic is evenly divisible by the divisor, divide in the usual manner and retain the is evenly divisole by the divisor, divide in the usual manner and retain the negative sign for the characteristic in the quotient. But if the negative characteristic is less than, or not evenly divisible, and prefix and such a negative number to it as will make it evenly divisible, and prefix an equal positive number to the decimal part of the logarithm; then divide the increased negative characteristic by the divisor, to obtain the characteristic of the quotient desired. To obtain the decimal part of the quotient, divide the decimal part of the logarithm, with the positive number prefixed, in the usual manner. To this quotient prefix the negative characteristic already found, and this will be the quotient desired.

EXAMPLE 1.—
$$\frac{\bar{6}.3246846}{3} = \bar{2}.1082282.$$
EXAMPLE 2.—
$$\frac{\bar{14}.3268472}{9} = (\bar{14} + \bar{4} = \bar{18}) + (4 + .3268472) \frac{\bar{18} + 4.3268472}{9} = \bar{2}.4807608.$$
EXAMPLE 3.—
$$\sqrt[6]{.677} = \frac{\log .677}{5} = \frac{\bar{1}.830589}{5}; \frac{\bar{5}}{5} + \frac{4.830589}{5} = \bar{1}.9661178 = .9249 + .$$

GEOMETRY.

PRINCIPLES OF GEOMETRY.

 The sum of all the angles formed on one side of a straight line equals. two right angles, or 180°.

2. The sum of all the angles formed around a point equals four right

angles, or 360°.
3. When two straight lines intersect each other, the opposite or vertical angles are equal.

4. If two angles have their sides parallel, they are equal.
5. If two triangles have two sides, and the included angle of the one equal to two sides and the included angle of the other, they are equal in all their parts.

If two triangles have two angles, and the included side of the one equal to two angles and the included side of the other, they are equal in all their

7. In any triangle, the greater side is opposite the greater angle, and the

greater angle is opposite the greater side.
8. The sum of the lengths of any two sides of a triangle is greater than

the length of the third side. 9. In an isosceles triangle, the angles opposite the equal sides are equal.

10. In any triangle, the sum of the three angles is equal to two right angles, or 180°. 11. If two angles of a triangle are given, the third may be found by

subtracting their sum from two right angles, or 180°.

12. A triangle must have at least two acute angles, and can have but one obtuse or one right angle.

13. In any triangle, a perpendicular let fall from the apex to the base is shorter than either of the two other sides.

- 14. In any parallelogram, the opposite sides and angles are equal each to each.
- 15. The diagonals divide any paralellogram into two equal triangles.
 16. The diagonals of a parallelogram bisect each other; that is, they divide each other into equal parts.

17. If the sides of a polygon be produced in the same direction, the sum of the exterior angles will equal four right angles.

18. The sum of the interior angles of a polygon is equal to twice as many right angles as the polygon has sides, less four right angles. Example.—The sum of the interior angles of a quadrilateral = (2×4)

-4 = 4 right angles. The sum of the interior angles of a pentagon = $(2 \times 5) - 4 = 6$ right angles. The sum of the interior angles of a hexagon $= (2 \times 6) - 4 = 8$ right angles.

19. In equiangular polygons, each interior angle equals the sum divided

by the number of sides.

20. The square described on the hypotenuse of a right-angled triangle is equal to the sum of the squares described on the other two sides. Thus, in a right-angled triangle whose base is 20 ft. and altitude 10 ft., the square of the hypotenuse equals the square of 20 + the square of 10, or 500. Then the hypotenuse equals the square root of 500, or 22.3607 ft.

21. Having the hypotenuse and one side of a right-angled triangle, the other side may be found by subtracting from the square of the pytotenuse the square of the other known side. The remainder will be the square of

the required side.

Triangles that have an angle in each equal, are to each other as the product of the sides including those equal angles.

23. Similar triangles are to each other as the squares of their correspond-

ing sides.

24. The perimeters of similar polygons are to each other as any two corresponding sides, and their areas are to each other as the squares of those sides.

The diameter of a circle is greater than any chord.

26. Any radius that is perpendicular to a chord, bisects the chord and the arc subtended by the chord.

27. Through three points not in the same line, a circumference may be made to pass.

DIRECTIONS.—Draw two lines connecting the three points. Erect perpendiculars from the centers of each of these two lines, and the point of inter-

section of the perpendiculars will be the center of the circle. 28. The circumferences of circles are to each other as their radii, and

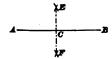
their areas are to each other as the squares of their radii EXAMPLE 1.—If the circumference of a circle is 62.83 in. and its radius is

10 in., what is the circumference of a circle whose radius is 15 in.?

10: 15:: 62.83: 94.245 in. Ans. EXAMPLE 2.—If a circle 6 in. in diameter has an area of 28.274 sq. in., what is the area of a circle 12 in. in diameter?

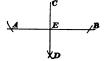
32: 62:: 28.274: 113.096 sq. in. Ans.

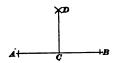
PRACTICAL PROBLEMS IN GEOMETRICAL CONSTRUCTION.



To Bisect a Given Straight Line A B .- From A and B as centers, with a radius greater than one-half of AB, describe arcs intersecting at E and F. Draw EF. It will bisect AB. C will be the middle point, and EF will be perpendicular to AB. The points E and F will be equidistant from A, B, or C.

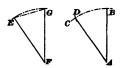
From a Given Point C, Without a Straight Line AB, to Draw a Perpendicular to the Line.—From C as a center, with a radius sufficiently great, describe an arc cutting AB in points A and B; then from A and B as centers, with a radius greater than one-half of AB, describe two arcs cutting each other at D. and draw CD.

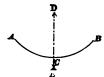




At a Given Point C in a Streight Line AB, to Erect a Perpendicular to That Line.—Take the points A and B equally distant from C, and, with A and B as centers, and a radius greater than one-half of AB, describe two arcs cutting each other at D, and draw the line DC.

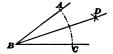
At a Point A on a Given Straight line A B, to Make an Angle Equal to a Given Angle EFG. From F as a center, with any radius F G, describe the arc EG. From A as a center, with the same radius, describe the arc CB; then with a radius equal to the chord EG, describe an arc from B as a center, cutting CB at D, and draw A D

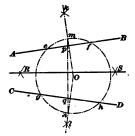




To Bisect a Given Arc $A\ C\ B$.—With the same radii and the extremities $A\ B$ as centers, describe arcs intersecting at D and E. The line $D\ E$ bisects the arc at C.

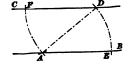
To Bisect an Angle A B C.—With any radius and B as a center, describe an arc cutting the sides at A and C. With these points as centers, describe arcs of equal radius intersecting at D. The line B D is the bisector, and the \angle A B D = \angle D B C.





To Bisect an Open Aigle (Method by L. L. Logan).—Let AB and CD be the sides of an open angle. With any point O as a center, describe a circle cutting the sides at e, f, g, and h, and with e and f, and g and h as centers and any radius, describe a resintersecting at k and l, respectively. Draw Ok and Ol and mn. With p and q as centers, and any radius, describe ares intersecting at R and R. The line drawn through R R is the required bisector.

Through a Given Point A, to Draw a Straight Line Parallel to a Given Straight Line CD.—From A as a center, with a radius greater than the shortest distance from A to CD, describe an indefinite arc DE. From D as a center, with the same radius, describe the arc AF. Take DE equal to AF, and draw AB.





To Find the Center of a Given Circumference or Arc. Take any three points A, B, and C on the circumference, and unite them by the lines A B and B C. Bisect these chords by the perpendiculars D O and E O; their intersection is the center of the circle.

Through a Given Point P, to Draw a Tangent to a Given Circle.—1. If P be in the circumference: Find C the center of the circle, draw the radius C P, and draw D E perpendicular to C P.





2. If P be without the circle: Join P and the center of the circle. Bisect PC in D; with D as a center, and a radius D C, describe the circumference intersecting the given circumference at A and B. From the intersections A and B, draw B P and A P.

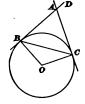
An acute angle having its vertex in the circumference and subtended by an arc is equal to one-half the central angle subtended by the same arc. Thus, the \angle A B C = $\frac{1}{4}$ \angle A O C.





An acute angle included between a chord and a tangent is equal to one-half the central angle subtended by the chord. Thus, \angle ABC = $\frac{1}{2}$ \angle COB.

If, from a point, two tangents be drawn to a circle, they will be equal, and their angle of intersection will be equal to the central angle subtended by the chord joining the two points of tangency. Thus, AB = AC, and $\angle DAC = \angle BOC$.





To Divide a Straight Line Into Any Number of Equal Parts.—To divide the line AB into, say, 6 parts, draw the line AC from A, making any angle with AB; measure off 6 equal spaces on AC; draw 6B, and from 1, 2, 3, 4, 5 on AC draw parallels to 6B. These divide AB as required into 6 equal parts.

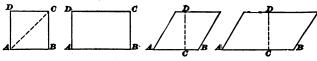
By a similar process a line may be divided into a number of unequal parts. Set off on A C divisions proportional to the required divisions, and draw the parallel lines as explained above.

MENSURATION.

MENSURATION OF SURFACES.

PARALLELOGRAMS.

A parallelogram is a four-sided figure whose opposite sides are parallel.



Square. (Four equal sides and four right an- and opposite sides ales.)

Rectangle. (Four right angles equal.)

Rhombus. (Four equal sides and oblique angles.)

Rl.omboid. (Four oblique angles and opposite sides equal.)

To find the Area of Any Parallelogram.—Multiply the length of any side by the length of a perpendicular line from that side to the opposite one. Thus, in the foregoing figures, the areas of the square and rectangle are found by multiplying the length AB by the height BC. The areas of the rhombus and rhomboid are found by multiplying the length AB by the height CD.

neight CD.

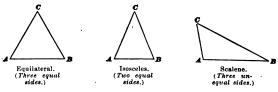
To Find the Diagonal of a Square.—Multiply the length of a side by 1.41421. Having the Diagonal, to Find the Side of a Square.—Divide the diagonal by 1.41421, or multiply it by .707107.

To Find a Square Equal in Area to a Given Circle.—Multiply the diameter of the circle by .886227, and the result will be the side of the required square. To Find the Area of the Largest Square That May be inscribed in a Circle. Square the radius of the circle, and multiply by 2.

To Find the Side of the Largest Square That May be inscribed in a Circle. Divide the diameter of the circle by 1.41421, or multiply it by .707107.

TRIANGLES.

A triangle is a figure having three straight sides.



To Find the Area of a Triangle.—Multiply its base by one-half the perpendicular height, or altitude.

To Find the Perpendicular Height of an Equilateral Triangle.—Multiply the length of one of its sides by .866025.

To Find the Length of Each Side of an Equilateral Triangle.—Divide the per-

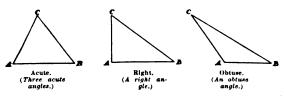
pendicular height by .866025, or multiply the perpendicular height by 1.1547. Or, take the square root of the area and multiply it by 1.51967.

To Find the Side of a Square of Same Area as an Equilateral Triangle. - Multhe length of one of its sides by .658037.

To Find the Diameter of a Circle of Same Area as an Equilateral Triangle. Divide the length of one of its sides by 1.34677.

The following rules apply to any triangle:

Having Two Sides and the included Angle, to find the Area.—Multiply together the two sides and the natural sine of the included angle, and divide the product by 2. Or, by logarithms, add together the logarithms of the two



sides and the logarithmic sine of the included angle, and from the sum subtract the logarithm of 2, and the result will be the logarithm of the area.

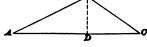
Having Three Sides of a Triangle, to find the Area.—Add the three sides together, divide the sum by 2; from the half sum, subtract each side separately; multiply the half sum and the three remainders continuously together, and extract the square root of the product. Thus, if the triangle

has three sides whose lengths are 30, 40, and 50 ft., then $\frac{30 \pm 40 \pm 50}{2}$

Then, subtracting from this 60 each side separately, we have: 60 - 30 = 30; 60-40=20; 60-50=10. Then, $60\times30\times20\times10=360,000$. The square root of 360,000=600 sq. ft., or area. Having the Three Sides of a Triangle, to Find its Angles.—In the triangle ABC, let AB=21 ft., BC=17.25 ft., and AC=32 ft. Draw BD per-

A B C, let A B - 2; then, pendicular to A C; then, 32:21+17.25=21-17.25:A D - D C; or, But $\begin{array}{lll} A \ D - D \ C = & 4.48 \\ A \ D + D \ C = & 32 \end{array}$ Adding, 2 A D = 36.48

AD = 18.24Subtracting.



$$\cos A = \frac{18.24}{21} = .86857$$
, or $A = 29^{\circ} 42' 25.7''$.
 $\cos C = \frac{13.76}{17.25} = .79768$, or $C = 37^{\circ} 5' 26.7''$.
 $(A + C) = 180 = .09042' 25.7'' + 37^{\circ} 5' .98.7''$.

 $B = 180^{\circ} - (A + C) = 180 - (29^{\circ} 42' 25.7'' + 37^{\circ} 5' 26.7'') = 113^{\circ} 12' 7.6''.$ Having Two Sides and Included Angle, to Find Third Side and the Other Angles. In the triangle ABC, let AB=19 ft., $AC=2^\circ$ ft., and $A=36^\circ$ 3' 29". Draw BD perpendicular to AC. $BD=19\times\sin A=19\times.58861=11.18$ ft. $AD = 19 \times \cos A = 19 \times .80842 = 15.36 \text{ ft.}$ DC = 23 - 15.36 = 7.64 ft.11.18 = 1.46335, or $C = 55^{\circ}$ 39' 10", B = 180 - (A + C) = 180

$$-(36° 3′ 29" + 55° 39′ 10") = 88° 17′ 21". BC = \frac{BD}{\sin C} = \frac{11.18}{.82562} = 13.54 \text{ ft.}$$

Having One Side and the Two Adjacent Angles, to Find the Other Two Sides. The third angle equals 180° minus the sum of the other two angles. This third angle will be the one opposite the given side. Then the sine of the angle opposite the given side is to the given side as the sine of either of the other angles is to its opposite side. Thus, in the triangle ABC, let $A=60^{\circ}$, $B=70^{\circ}$, and the side AB=200 ft. Then the angle $C=180^{\circ}$ - $(60^{\circ}+70^{\circ})$ = 50°.

sin 50°: 200:: sin 60°: B C, Then, sin 50°: 200 :: sin 70°: A C. and

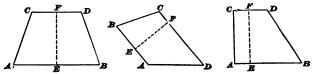
To Find the Area.—Either find the three sides as above, and follow rule already given, or multiply the natural sines of the two given angles together. Then, as the natural sine of the single angle is to the product of the sines of the given angles, so is the square of the given side to twice the required area.

Thus, $\sin C : \sin A \times \sin B :: \widehat{AB^2} :$ to twice the area of the triangle.

The area of any triangle is equal to half the area of a parallelogram having the same base and perpendicular height.

TRAPEZOIDS.

A transpoid has four straight sides, only two of which are parallel.



To Find the Area of a Trapezoid.—Add together the two parallel sides, and Multiply the quotient by the perpendicular height. $\frac{AB + CD}{2} \times EF = \text{area.}$ divide by 2.

Thus.

TRAPEZIUMS.

A trapezium has four sides, no two of which are parallel.

To Find the Area of a Trapezium.—Divide the trapezium into two triangles, and find the area of each according to the rules given under the head of "Triangles." Add together the areas of the two triangles, and the sum will equal the area of the trapezium. The sides and angles can be found in the same manner.

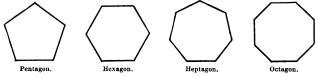


If the diagonals and the perpendiculars from them to the opposite angles are given, add together the two perpendiculars, multiply the sum by the diagonal, and divide by 2.

The sum of the four angles included in a trapezium always equals four right angles.

POLYGONS.

All figures bounded by more than four straight lines are called polygons.



If all the sides and angles are equal, it is a regular polygon. If not, it is an irregular polygon.

The sum of the interior angles of any polygon is equal to twice as many right angles as the polygon has sides, less four right angles.

To Find the Area of Any Regular Polygon.—Square one of its sides and multiply by the number given in the column of areas in the following Or, multiply the length of one of the sides by one-half the length of a perpendicular drawn to the center of the figure, and this product by the number of sides.

Having the Side of a Regular Polygon, to Find the Radius of a Circumscribing Circle.—Multiply the side by the corresponding number in following column of outer radii. If the radius of the circumscribing circle be given,

divide it by the number in column of outer radii, and the quotient will be the side of the polygon.

To Find the Area of an Irregular Polygon.-Divide it into triangles, find the

TABLE OF REGULAR POLYGONS WHOSE SIDES ARE UNITY.

Number of Sides.	Name of Polygon.	Areas.	Outer Radii.	Angles Contained Between Two Sides.	Angle at Center of Circle.	
3	Equilateral triangle	.4330	.5774	60°	1200	
4	Square	1.0000	.7071	900	90°	
5	Pentagon	1.7205	.8507	108°	720	
6 7	Hexagon	2.5981	1.0000	120°	600	
	Heptagon	3.6339	1.1524	128° 34′ 17"+	51° 25′ 43′′—	
8	Octagon	4.8284	1.3066	1350	45°	
9	Nonagon	6.1818	1.4619	140°	40°	
10	Decagon	7.6942	1.6180	1440	360	
11	Undecagon	9.3656	1.7747	147° 16′ 22′′-	32° 43′ 38"+	
12	Dodecagon	11.1962	1.9319	150°	30°	

area of each triangle, and add them together. The sum will be the area

of the polygon.

To Find the Area of a Figure Whose Outlines Are Very Irregular.—Draw straight lines around it that will enclose within them (as nearly as can be judged) as much space not belonging to the figure as they exclude space belonging to it. The area of the figure thus formed may be easily found by dividing into triangles.

CIRCLES.

(See Table of Areas of Circles, Etc.)

A circle is a figure bounded by a curved line, every point of which is equidistant from the center. Or, a circle is a regular polygon of an infinite number of sides.

The circumference of a circle equals the diameter multiplied by 3.1416, or the square root of the product of the area multiplied by 12.566.

To find the Diameter.—Divide the circumference by 3.1416, or multiply it by .31831.

To Find the Area of a Circle. - Multiply the circumference by one-fourth of the diameter, or the square of the radius by 3.1416. Multiply the square of the diameter by 7854, or the square of the circumference by .07958.

To Find the Diameter of a Circle Equal in Area to a Given Square.—Multiply one side of the square by 1.12838.

To Find the Radius of a Circle to Circumscribe a Given Square.—Multiply one side by .7071; or take one-half the diagonal. To Find the Side of a Square Equal in Area to a Given Circle.—Multiply the

diameter by .88623. To Find the Side of the Greatest Square in a Given Circle.-Multiply the

diameter by .7071. To Find the Area of the Greatest Square in a Given Circle.—Square the radius

and multiply by 2. To Find the Side of an Equilateral Triangle Equal in Area to a Given Circle.

Multiply the diameter by 1.3468.

Having the Chord and Rise of an Arc, to Find the Radius.—Square half the chord, and divide by the rise. To the quotient add the rise, and divide by 2. Or, radius = the square of the chord of half the arc divided by twice the rise of the whole arc.

Having the Chord and Radius, to Find the Rise.—Square the radius, also square half the chord. Take the last square from the first. Extract square not of the remainder, and subtract it from the radius if the radius is greater; if not, add it to the radius.

Having the Radius and Rise, to Find the Chord.—From the radius subtract the rise (or from the rise subtract the radius, if rise is the greater), square

the remainder, and subtract it from the square of the radius. Extract the square root of the remainder, and multiply by 2.

Having the Rise of the Arc and Diameter of Circle, to Find the Chord.—Su tract the rise from the diameter, and multiply the remainder by the rise... Extract the square root of the product, and multiply by 2.

To Find the Breadth of a Circular Ring, Having Its Area and the Diameter of the Outer Circle.—Find the area of the whole circle, and from it take the area of the ring. Multiply the remainder by 1.2732, and the square root of the product will be the diameter of the inner circle. Take it from the diameter of the outer one, and the remainder will be twice the breadth.

To Find the Area of a Circular Ring.—Take the difference of the squares of the radii, and multiply it by 3.1416.

To Find the Length of an Arc When its Degrees and Radius Are Given.—Multiply the number of degrees by .01745, and the product by the

To find the Area of a Sector .- Multiply the arc by one-half the radius. The area of the sector is to the area of the circle as the number of degrees in the sector is to 360°.

To find the Area of a Segment.-Find the area of the sector having the same arc, and also the area of the triangle formed by the chord of the segment and the radii of the sector. If the segment is greater than a semicircle, add the two areas: if less, subtract them.

THE ELLIPSE.

To find the Area of an Ellipse.—Multiply one-half of the two axes AB and CD together, and multiply the product by 3.1416.

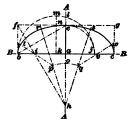
To find the Perimeter of an Ellipse.—Multiply one-half

the sum of the two axes by 3.1416

To Draw an Approximate Ellipse (Method by Three Squares). Let a be the center, bc the major, and ae half the minor axis of an ellipse. Draw the rectangle bfgc, and the

axis of an ellipse. Draw the rectangle v, y, c, and adiagonal line be; at a right angle to be, draw line fh cutting BB at i. With radius ae, and from a as a center, draw the dotted are ej, giving the point j on the line BB. From k, which is central between b and j, draw the semicircle bmj, cutting AA at D raw the radius of the semicircle bmj, cutting fg at n. With radius mn, mark the radius of the semicircle b m j, cutting fg at n. With radius m n, mark on AA, at and from a as a center, the point o. With radius ho, and from

center h, draw the arc $p \circ q$. With radius a l, and from b and c as centers, draw arcs cutting $p \circ q$ at the points p and q. Draw the lines hpr and hqs, and also the lines pit From h as a center, draw that part of the ellipse lying between r and swith radius h r. From p as a center draw that part of the ellipse lying between r and From q, draw the t with the radius pr. ellipse from s to w. With radius it, from i as a center, draw the ellipse from t to b with radius it, and from vasa center, draw the ellipse from w to c, and one-half the ellipse will be drawn. It will be seen that the whole construction has been performed to find the centers h, p, q, i, and v, and that while v and i



may be used to carry the curve around the other side or half of the ellipse. new centers must be provided for h, p, and q; these new centers correspond in position to h, p, q.



Straightedge Method.—On a straightedge, lay off AB equal to one-half the short diameter and A C equal to one-half the long diameter. Determine points on the circumference of the ellipse by marking positions of A, as the point B is moved along the major axis and, at the same time, the point C along the minor axis.

MENSURATION OF SOLIDS.

THE CUBE AND THE PARALLELOPIPED.

Te Find the Surface of a Cube.—Multiply the area of one side by 6.
To Find the Surface of a Parallelopiped.—Add together twice the area of the base, twice the area of the side, and twice the area of the end. To Find the Cubical Contents of a Cube or Parallelopiped .- Multiply the area

of the base by the perpendicular height.



THE PRISM.

To Find the Convex Surface of a Right Prism.—Multiply the perimeter of the base by the altitude.

To find the entire surface, add the areas of the bases.
To Find the Contents of a Prism.—Multiply the area of the base by the altitude of the prism.

THE CYLINDER.

To Find the Convex Surface of a Cylinder.—Multiply the circum-

ference of the base by the altitude.

To find the entire surface, add the areas of the ends.

To Find the Contents of a Cylinder.-Multiply the area of the base by the altitude.



THE SPHERE.

To Find the Surface of a Sphere.-Multiply the diameter by the circumference; or, square the radius and multiply it by 4 and 3.1416.

To Find the Contents of a Sphere.—Multiply the surface by one-third of the radius; or, multiply the cube of the diam-

eter by .5236.

To Find the Surface of a Zone.—Multiply the height of the zone by the circumference of a great circle of the sphere. To Find the Contents of a Spherical Segment of One Base.
Add the square of the height to three times the square of the radius of the base; multiply this sum by the height,

and the product by .5236.

The curved surface on a hemisphere is equal to twice its plane surface, and the curved surface on a quarter of a sphere is equal to its plane surface.

THE PYRAMID.

To Find the Convex Surface of a Pyramid.—Multiply the perimeter of the base by one-half the slant height.

To find the entire surface, add the area of the base.

To find the Contents of a Pyramid.—Multiply the area of the base by one-third of the altitude.





THE CONE.

To Find the Convex Surface of a Cone.—Multiply the circumference of the base by one-half the slant height.

To find the entire surface, add the area of the base.

To Find the Contents of a Cone.—Multiply the area of the base by one-third of the altitude.

THE FRUSTUM OF A PYRAMID OR CONE.

To Find the Convex Surface .- Multiply one-half of the sum of the perimeters or circumferences of the two bases



by one-half the slant height. The entire surface is found by adding

the areas of the two bases.

To Find the Contents of a Frustum.—Add together the sum of the two bases and the square root of their product, and mul-

tiply the sum by one-third of the altitude of the frustum.

CYLINDRICAL RINGS.

A cylindrical ring is formed by bending a cylinder or pipe until its two ends meet.

To Find the Surface of a Cylindrical Ring.—To the thickness of the ring, add the inner diameter, multiply this sum by the thickness of the ring, and the product by 9.8696.

To Find the Contents of a Cylindrical Ring.—To the thickness of the ring add the inner diameter, multiply this sum by

the square of one-half the thickness.

To Find the Volume of an irregular Body.—Fill a vessel of known dimensions with water, and immerse the body. The contents will equal the volume of water displaced.

THE PRISMOIDAL FORMULA.

This formula is the invention of Mr. Elwood Morris, C. E., of Philadelphia, and is extensively used in calculating the cubical contents of cuttings,

embankments, etc.

It embraces all parallelopipeds, prisms, pyramids, cones, wedges, etc., whether regular or irregular, right or oblique, with their frustums when cut parallel to their bases. In fact, it embraces all solids having two parallel faces or sides, provided these two faces are united by surfaces, whether plane or curved, on which, and through every point of which, a straight line may be drawn from one of the parallel faces to the other.

To find the Contents of Any Prismoid.—Add together the areas of the two parallel surfaces, and four times the area of the section taken half way

between them, and parallel to them; multiply the sum by the perpendicular

distance between the two parallel sides, and divide the product by 6.

PLANE TRIGONOMETRY.

Plane trigonometry treats of the solution of plane triangles.

In every triangle, there are six parts—three sides and three angles. These parts are so related that when three of the parts are given, one being a side, the other parts may be found.

An angle is measured by the arc included between its sides, the center of

the circumference being at the vertex of the angle.

For measuring angles, the circumference is divided into 360 equal parts called degrees; each degree into 60 equal parts called

minutes. A quadrant is one-fourth the circumference of a circle, or 90°.

The complement of an arc is 90° minus the arc; DC is the complement of BC, and the angle DOC is the

complement of BOC. The supplement of an arc is 180° minus the arc: AE

is the supplement of the arc BDE, and the angle BOE. In trigonometry, instead of comparing the angles of triangles or the arcs that measure them, we compare

the trigonometric functions known as the sine, cosine, tangent, cotangent, secant, and cosecant.

The sine of an arc is the perpendicular let fall from one extremity of the





COTANGENT

COSINE

arc on the diameter that passes through the other extremity. Thus, CD is the sine of the arc A C.

The cosine of an arc is the sine of its complement; or it is the distance from the foot of the sine to

the center of the circle. Thus, CE or OD equals the

cosine of arc A C.

The tangent of an arc is a line that is perpendicular to the radius at one extremity of an arc and limited by a line passing through the center of the circle and the other extremity. Thus, A T is the tangent of A C.

The cotangent of an arc is

equal to the tangent of the complement of the arc. Thus, B T is the cotangent

of AC.

The secant of an arc is a few the center line drawn from the center

of the circle through one extremity of the arc, and limited by a tangent at the other extremity. Thus, O T is the secant of A C.

The cosecant of an arc is the secant of the complement of the arc. Thus, O T' is the cosecant of A C.

The versed sine of an arc is that part of the diameter included between the extremity of the arc and the foot of the sine. DA is the versed sine of AC. The coversed sine is the versed sine of the complement of the arc. Thus, BE is the coversed sine of A C.

From the above definitions, we derive the following simple principles: The sine of an arc equals the sine of its supplement, and the cosine of an

arc equals the cosine of its supplement. 2. The tangent of an arc equals the tangent of its supplement, and the cotan-

gent of an arc equals the cotangent of its supplement.

3. The secant of an arc equals the secant of its supplement, and the cosecant

equals the cosecant of its supplement.

Thus.

 $70^{\circ} = \text{sine of } 110^{\circ}.$ cosine of $70^{\circ} = \text{cosine of } 110^{\circ}$ sine of agent of 70° = tangent of 110°. cotangent of 70° = cotangent of 110°.

ant of 70° = secant of 110°. cosecant of 70° = cosecant of 110°.

Thus, if you want to find the sine of an angle of 120° 30′, look for the sine tangent of 70° = tangent of 110° . secant of 70° = secant of 110° .

of 180 - 120° 30', or 59° 30', etc.

In the rt. $\triangle xyz$, the following relations hold:



$$\sin c = \frac{b}{h}$$
. $\cos c = \frac{b}{c}$
 $\tan c = \frac{b}{a}$. $\cot c = \frac{c}{c}$
 $\sec c = \frac{h}{c}$. $\csc c = \frac{c}{c}$

Functions of the sum and difference of two angles:

$$\sin (A + B) = \sin A \cos B + \cos A \sin B,$$

$$\cos (A + B) = \cos A \cos B - \sin A \sin B,$$

$$\sin (A - B) = \sin A \cos B - \cos A \sin B,$$

$$\cos (A - B) = \cos A \cos B + \sin A \sin B.$$

Natural sines, tangents, etc. are calculated for a circle whose radius is unity, and logarithmic sines, tangents, etc. are calculated for a circle whose radius is 10,000.000.000.

PRACTICAL EXAMPLES IN THE SOLUTION OF TRIANGLES.

CASE 1. To Determine the Height of a Vertical Object Standing on a Horizontal Plane. - Measure from the foot of the object any convenient horizontal distance AB; at the point A, take the angle of elevation BAC. Then, as Bis known to be a right angle, we have two angles and the included side of a triangle.

Assuming that the line AB is 300 ft. and the angle $BAC=40^\circ$, the angle $C=180^\circ-(90^\circ+40^\circ)=50^\circ$. Then, $C:AB::\sin A:BC$.



.766044 : 300 :: .642788 : (), or 251.73+ ft. Or, by logarithms:

Log 300 = 2.477121 $Log \sin 40^{\circ} =$ 9.808067 12.285188 $Log \sin 50^{\circ} = 9.884254$

2.400934 or log of 251.73+ ft. Hence, BC = 251.73 + ft.

CASE 2. To Find the Distance of a Vertical Object Whose Height is Known.—Ata point A, take the angle of elevation to the top of the object. Knowing that

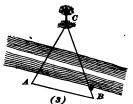
.5:200:: .866025: (), or 346.41 ft. or

By logarithms: Log 200 =2.301030 $Log \sin 60^{\circ} =$ 9.937531 12.238561 $Log sin 30^{\circ} =$ 9.698970

2.539591 or log of 346.41 ft.



CASE 3. To Find the Distance of an Inaccessible Object.-Measure a horizontal base line AB, and take the angles formed by the lines BAC and ABC We then have two angles and the included side. Assuming the angle A to be 60°, the angle B 50°, and the side AB = 500 ft., we



have the angle $C = 180^{\circ} - (60^{\circ} + 50^{\circ}) = 70^{\circ}$. Then, sin 70°: AB:: sin A:BC, and sin 70°: AB:: sin B:A:C, or. 989693: 500:: .866025: BC, or 460.8+, and .939693: 500:: .766044: AC, or 407.6+.

By logarithms: Log 500 = 2.698970 $Log \sin 60^{\circ} = 9.937531$ 12,636501 $Log \sin 70^{\circ} = 9.972986$

 $2.663515 = \log of 460.8 + .$

Log 500 = 2.698970 $Log \sin 50^{\circ} = 9.884254$ 12.583224 $Log sin 70^{\circ} = 9.972986$

 $2.610238 = \log of 407.6 + .$

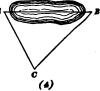
CASE 4. To Find the Distance Between Two Objects Separated by an Impassible Barrier.—Select any convenient station, as C, measure the lines CA and CB, and the angle included between these sides. Then we have

two sides and the included angle.

Assuming the angle C to be 60°, the side CA, 600 ft., and the side CB, 500 ft., we have the

following formula: $CA + CB : CA - CB :: \tan \frac{A+B}{2} : \tan \frac{B-A}{2}$. Then, $\frac{A+B}{2} = \frac{180^{\circ} - 60^{\circ}}{2}$, or 60° .

 $1,100:100::\tan 60^{\circ}:\tan \frac{B-A}{3}$ Then.



or,
$$1,100:100::1.732050:.157459$$
, or tangent of $\frac{B-A}{3}$, or 8° 57′.

Then, $60^{\circ} + 8^{\circ} 57' = 68^{\circ} 57'$, or angle \tilde{B} , d $60^{\circ} - 8^{\circ} 57' = 51^{\circ} 03'$, or angle A. Having found the angles, find the third side by the same method as Case 1. and

The above formula, worked out by logarithms, is as follows: Log 100 = 2.000000

$$\begin{array}{r} \text{Log } 100 = 2.00000 \\ \text{Log tan } 60^{\circ} = 10.238561 \\ \hline 12.238561 \\ \text{Log } 1,100 = 3.041393 \\ \hline 9.197168 \\ \hline \end{array}$$

$$Log 1,100 = \frac{\overline{12.288561}}{3.041393}$$

$$\overline{9.197168} = \log \tan \text{ of } \frac{B-A}{2}, \text{ or } 8^{\circ} 57'.$$

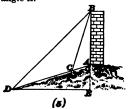
Then, and

$$60^{\circ} + 8^{\circ} 57' = 68^{\circ} 57'$$
, or angle B, $60^{\circ} - 8^{\circ} 57' = 51^{\circ} 03'$, or angle A.

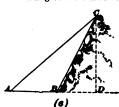
Note.—The greater angle is always oppo-

site the greater side. CASE 5. To Find the Height of a Vertical

Object Standing Upon an Inclined Plane. - Measure any convenient distance D C on a line from the foot of the object, and, at the point D, measure the angles of elevation EDA and EDB to foot and top of tower. We then have two triangles, both of which may be solved by Case 1, and the height above D of both the foot and top will be known. The difference between them is the height of the tower.



CASE 6. To Find the Height of an Inaccessible Object Above a Horizontal Plane. Measure any convenient horizontal line AB directly toward the object, and take the angles of elevation at A and B. We will then have sufficient data

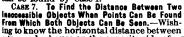


to work with. Assuming the line AB to be 1,200 ft. long, the angle A, 25°, and the angle BBC, 40°, we have the following: As the angle DBC is 40°, the angle $ABC = 90^{\circ}$

Then, having the side BC, and the angle $DBC = 40^{\circ}$, and the angle $BDC = 90^{\circ}$, we find the side CD by the same method as in Case 1.

Second Method.-If it is not convenient to measure a horizontal base line toward the object, measure any line AB, Fig. (6a), and also measure the horizontal angles BAD, ABD, and the angle of elevation DBC.

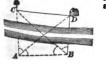
Then, by means of the two triangles ABDand CBD, the height CD can be found. Then, with the line AB and the angles BAD and ABD known, we have two angles and the included side known. The third angle is readily found, and the side BD can be found. Then, in the triangle BDC, we have the angle B; by measurement, $D=90^{\circ}$, and we have the side BD. Then, the side CD, or the vertical height, can be found by Case 1.





a tree and a house on the opposite side of a river, measure the line AB, and, at point A, take the angles DAC, and DAB, and, at the point B, take the angles CBA and CBD.

Assume the length of AB = 400 ft.



Angle
$$DAC = 56^{\circ}30'$$
.
Angle $DAB = 42^{\circ}24'$.
Angle $CBA = 44^{\circ}36'$.
Angle $CBD = 68^{\circ}50'$.

In the triangle ABD, we have $AB \sim 400$ ft., the angle $DAB = 42^{\circ}24'$ the angle $ABD = (44^{\circ}36') = 68^{\circ}5') = 113^{\circ}26'$, and the angle $ADB = 180' = (42^{\circ}24' + 118^{\circ}26') = 24^{\circ}10'$. Then, according to Case I, find the side DB. We then have three angles and two sides of the triangle ADB. We find the third side ADB to Case I.

Then in the triangle ABC, we have the angles ABC and BAC, and the distance AB. From these we find the side AC. Then, in the triangle ADC we have the sides AD and AC, and the angle DAC, and we then find the

side CD by Case 4.

SURVEYING.

Surveying is an extension of mensuration, and, as ordinarily practiced, may be divided into surface work, or ordinary surveying, and underground work, or mine surveying. With slight modifications, the instruments employed in both are the same, and consist of a compass—if the work is of little importance, and accuracy is not required—a transit, level, transit and level rods, steel tape or chain, and measuring pins, and sometimes certain accessory instruments, as clinometers or slope levels, dipping needles, etc., as will be described later.

As the instrumental work is generally the same in both kinds of surveying, a description of the instruments and the usual practice on the surface will be first given, and afterwards an account of the methods of mine surveying as practiced in the anthractic regions of Pennsylvania, with the

deviations from the practice of the former.

THE COMPASS.

The compass may be either a pocket compass, or a surveyor's compass, and may be used by holding in the hand, or with a tripod. The Jacob's staff, convenient for use on the surface, is frequently useless in the mine. The compass is not accurate enough for the construction of a general map of the mine. It is useful inasmuch as it enables the mine foreman to readily secure an approximate idea of the shape of the workings, and, from a plan constructed by its use, he can get an approximate course on which to drive an opening designed to connect two or more given points. If the opening is one that will be expensive to drive, and should be straight, the compass survey should never be relied on.

TO ADJUST THE COMPASS.

The Levels.—First bring the bubbles into the center by the pressure of the hand on different parts of the plate, and then turn the compass half way around; should the bubbles run to the ends of the tubes, it would indicate that those ends were the higher; lower them by tightening the screws immediately under, and loosening those under the lower ends until, by estimation, the error is half removed; level the plate again, and repeat the first operation until the bubbles will remain in the center during an entire revolution of the compass.

The sights may next be tested by observing through the slits a fine hair or thread, made exactly vertical by a plumb. Should the hair appear on one side of the slit, the sight must be adjusted by filing off its under surface on

the side that seems the higher.

The needle is adjusted in the following manner: Having the eye nearly in the same plane with the graduated rim of the compass circle, with a small splinter of wood, or a slender iron wire, bring one end of the needle in line with any prominent division of the circle, as the zero or 90° mark, and notice if the other end corresponds with the degree on the opposite side; if it does the needle is said to cut opposite degrees; if not, bend the center pin by applying a small brass wrench, furnished with most compasses, about one eighth of an inch below the point of the pin, until the ends of the needle are brought into line with the opposite degrees.

Then, holding the needle in the same position, turn the compass half way around, and note whether it now cuts opposite degrees; if not, correct half the error by bending the needle, and the remainder by bending the center pin. The operation must be repeated until perfect reversion is secured in the

first position. This being obtained, it may be tried on another quarter of the

circle; if any error is there manifested, the correction must be made in the center pin only, the needle being already straightened by the previous

When again made to cut, it should be tried on the other quarters of the circle, and corrections made in the same manner until the error is entirely removed, and the needle will reverse in every point of the divided circle.

TO USE THE COMPASS.

In using the compass, the surveyor should keep the south end toward his person, and read the bearings from the north end of the needle. In the surveyor's compass, he will observe that the position of the E and W letters on the face of the compass are reversed from their natural position, in order that the direction of the sight may be correctly read.

The compass circle being graduated to half degrees, a little practice will enable the surveyor to read the bearings to quarters—estimating with his

eye the space bisected by the point of the needle.

The compass is usually divided into quadrants, and zero is placed at the north and south ends. 90° is placed at the E and W marks, and the graduations run right and left from the zero marks to 90°. In reading the bearing, the surveyor will notice that if the sights are pointed in a N W direction, the north end of the needle, which always points approximately north, is to the right of the front sight or front end of the telescope, and, as the number of degrees is read from it, the letters marking the cardinal points of the compass read correctly. If the E, or east, mark were on the right side of the circle, a N W course would read N E. This same remark applies to all four quadrants. The compass should always be in a level position.

MAGNETIC VARIATION.

Magnetic declination or veriation of the needle is the angle made by the magnetic meridian with the true meridian or true north and south line. It is east or west according as the north end of the needle lies east or west of the true meridian. It is not constant, but changes from year to year, and, for this reason, in rerunning the lines of a tract of land, from field notes of some years' standing, the surveyor makes an allowance in the bearing of

every line by means of a vernier that is so graduated that 30 spaces on it equal 31 on the limb of the instrument, as

shown in the figure. To Read the Vernier.—As the compass vernier is usually so made that there are but 15 spaces on each side of the zero mark, it is read as follows: Note the degrees and half

degrees on the limb of the instrument. If the space passed beyond the degree or half-degree mark by the zero mark on the vernier is less than one-half the space of half a degree on the limb, the number of minutes is, of course, less than 15, and must be read from the lower row of figures. If the space passed is greater than one-half the spacing on the limb, read the upper row of figures. The line on the vernier that exactly coincides with a line on the limb is the mark that denotes the number of minutes. If the index is moved to the right, read the minutes from the left half of the vernier; if moved to the left, read the right side of the vernier.

To Turn Off the Variation.—Moving the vernier to either side, and with it, of course, the compass circle attached, set the compass to any variation by placing the instrument on some well-defined line of the old survey, and by turning the tangent screw (slow-motion screw) until the needle of the compass indicates the same bearing as that given in the old field notes of the original survey. Then screw up the clamping nut underneath the vernier and run all the other lines from the old field notes without further alteration.

The reading of the vernier on the limb gives the amount of variation since

the original survey was made.

The accompanying map shows the general course and direction of isogonic lines (those passing through points where the magnetic needle has the same declination), in all parts of the United States and Mexico for the year 1900. These lines are drawn full when compiled from reliable records, but dotted in other places. The declination is marked in degrees at each end of every alternate line, the sign + indicating a west declination, and the sign - an east declination. The yearly variation, or change of declination, for the period 1895-1900 is marked in numerous places on the map. The annual change in declination is given in minutes; a + sign signifies increasing west or decreasing east declination, a - sign the reverse motion. Stations to the right of the agonic curve, or curve of no declination, have west declination and those to the left, east declination. The large black circles or dot indicate the capitals of the several states.

The use of this chart is quite simple. The declination for any place.

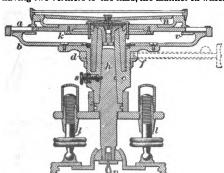
The use of this chart is quite simple. The declination for any place within its borders is either found by inspection or by simple interpolation between the two adjacent curves; the value found is for 1900. For any other year (and fraction), a reduction for secular change between the epoch and given date must be applied. The annual change of the declination during the period 1895-1900, expressed in minutes of arc, is indicated in the chart (+ for increasing west or decreasing east declination and - for the reverse motion). The amount varies in time, but not sufficiently during a brief interval of years to cause any serious inaccuracy, and the values given on the chart can be used for a number of years to come for all practical purposes; its variation with geographical position must be estimated from the map.

THE TRANSIT.

The transit is the only instrument that should be used for measuring angle in any survey where great accuracy is desired. The advantages of a transit over a vernier compass are mainly due to the use of a telescope. By its use angles can be measured either vertically or horizontally, and, as the vernier is used throughout, extreme accuracy is secured.

is used throughout, extreme accuracy is secured.

The illustration shows the interior construction of the sockets of a transit having two verniers to the limb, the manner in which it is detached from its



spindle, and how it can be taken apart when desired. The limb b is attached to the main socket c. which is carefully fitted to the conical spindle h, and held in place by the spring catch s.

The upper plate a. carrying the compass circle, standards etc., is fastened to the flanges of the socket k, which is fitted to the upper conical surface of the main socket c. The weight of all the parts is supported on the small bearings of the end

of the socket, as shown, so as to make as little friction as possible where such parts are being turned as a whole.

A small conical center, in which a strong screw is inserted from below, is brought down firmly on the upper end of the main socket c, thus holding the two plates of the instrument securely together, and, at the same time, allowing them to move freely around each other. The steel center pin on which the needle rests is held by the small disk fastened to the upper plate by two small screws above the conical center. The clamp to $\lim b \frac{d}{d}$, with clamp screw, is attached to the main socket. The instrument is leveled by means of the leveling screws l and placed exactly over a point by means of the shifting center. The plummet is attached to the loop p.

The verniers on a transit differ from those on a compass in detail only.



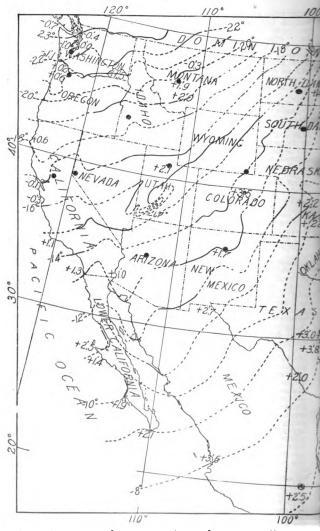
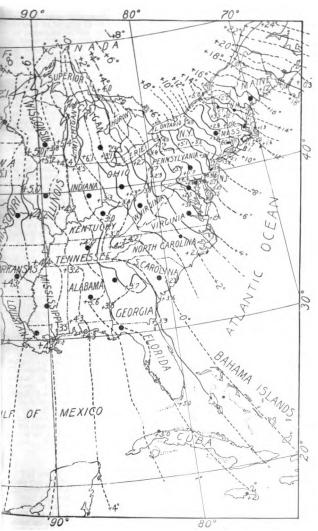


CHART SHOWING THE ISOGONIC AND AGONIC LINES IN THE UNITED STATE



EAR 1900, AND THE MEAN ANNUAL CHANGE FOR THE PERIOD 1885-1900.



The principle is the same. The transit vernier is so divided that 30 spaces on it equal in length 29 on the limb of the instrument. The method of reading it is practically the same as reading a compass vernier, except that on the transit the vernier is made with all of the 30 divisions on one side of the

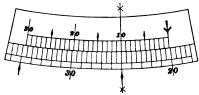
Each division of the vernier is therefore $\frac{1}{10}$, or, in other words, 1 minute

shorter than the half-degree graduations on the limb.

In the figure the reading is 20° 10°. If the zero on the vernier should be beyond 201° on the limb of the transit, and the line

marked 10 should coincide with a line on the limb, the reading would be 20° 40'. In case the 12th line from zero should coincide with a line on the limb, the reading would be 20° 42′, etc.

In some transits, the duated limb has two graduated limb has sets of concentric gradua-tions, the zero in both being



the same, and, while the outside set is marked from 0° each way to 90°, and thence to 0° on the opposite side of the circle, the other set is marked from 0° to 360° to the right, as a clock face. The inside set has the N, S, E, and W points marked, the 0° of the inside set being taken as morth.

The interior of the telescope is fitted up with a diaphragm or cross-wire to which cross-wires are attached. These cross-wires are either of ring to which cross-wires are attached. These cross-wires are either of platinum or are strands of spider web. For inside work, platinum should be used, as spider web is translucent and cannot readily be seen. They are set at right angles to each other and are so arranged that one can be adjusted so as to be vertical and the other horizontal. This diaphragm is suspended in the telescope by four capstan-headed screws, and can be moved in either direction by working the acrews with an ordinary adjusting pin. The transit should not be subjected to sudden changes in temperature that may break the cross-hairs. In case of a break, remove the cross-hair diaphragm and replace the broken wire.

The intersection of the wires forms a very minute point, which, when they are adjusted, determines the optical axis of the telescope, and enables

the surveyor to fix it upon an object with the greatest precision.

The imaginary line passing through the optical axis of the telescope is termed the line of collimation, and the operation of bringing the intersection of the wires into the optical axis is called the adjustment of the line of collimation.

All screws and movable parts should be covered, so as to keep out acid water or dust. If this is not done, the mine work will soon use up a transit. The vertical circle on the transit may be a full circle or a segment. The former is to be preferred, as it is always ready without intermediate clamp If the dip of a sight is to be taken, the tape must be held at the transit head, and stretched in the line of sight. If the pitch of the ground is to be taken, the point of foresight must be at the same height as the axis of the transit, and the sight will then be parallel to the surface. The angle of dip is read "plus" or "minus," as it is above or below the horizontal plane. If we have the dip of a sight, and the distance between the transit head and the point of sight we can get the vertical and hericardal components that the point of sight, we can get the vertical and horizontal components of that distance from the table of sines and cosines.

ADJUSTMENTS OF THE TRANSIT.

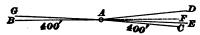
The use of a transit tends to disarrange some of its parts, which detracts from the accuracy of its work, but in no way injures the instrument itself. Correcting this disarrangement of parts is called adjusting the transit.

First Adjustment.—To make the level tubes parallel to the vernier plate.
Plant the feet of the tripod firmly in the ground. Turn the instrument until one of the levels is parallel to a pair of opposite leveling screws; the other level will be parallel to the other pair. Bring the bubble in each tube to the middle with the pair of leveling screws to which the tube is parallel. Next turn the vernier plate half way around; that is, revolve it through an angle of 180°. If the bubbles have remained in the middle of the tubes, the levels are in proper adjustment. If they have not remained so, but have

moved toward either end, bring them half way back to the middle of the tubes by means of the capstan-headed screws attached to the tubes, and the rest of the way back by the leveling screws. Again turn the vernier plate through 180°, and if the bubbles do not remain at the middle of the tuber repeat the correction. Sometimes the adjustment is made by one trial, but usually it is necessary to repeat the operation. Each level must be adjusted as caparately.

Second Adjustment.—To make the line of collimation perpendicular to the horizontal axis that supports the telescope.

With the instrument firmly set at A, and carefully leveled, sight to a primit or tack set at a point B, about 400 ft. distant, and on level or nearly levels.



ground. Reverse the telescope; that is, turn it over one its axis until it points in the opposite direction, and set a point at about the same dispersions which will be the same of the point at a bout the same dispersions.

fance, which will be at D. for example, if this adjustment needs correction. Unclamp the vernier plate, and, without touching the telescope, revolve the instrument about its vertical axis sufficiently far to take another sight upon the point B. Then turn the telescope on its axis and locate a third point, as at C. Measure the distance CD, and at E, one-fourth of the distance from C to D, set the pin or tack. Move the cross-hairs, by means of the capstan-headed screws, until the vertical hair exactly covers the pin at E, being careful to move it in the opposite direction from that in which it appears it should be moved. Having done this, and then having reversed the telescope, the line of sight will not be at the point E, but at E, a distance from E equal to CE. Again sight to E, then reverse, and the pin will be at E in the same straight line with E. It may be necessary to repeat the operation to secure an exact adjustment.

Third Adjustment.—To make the horizontal axis of the telescope parallel to the vernier plate, so that the line of collimation will revolve in a vertical plane.

Sight to some point A at the top of a building, so that the telescope will be elevated at a large angle. Depress the telescope, and set a pin on the ground below at a point B. Loosen the clamp, turn over the telescope, and turn the plate around sufficiently far to take an approximately accurate sight upon the point A. Then clamp the instrument and again take an exact sight to the point A. Next depress the telescope, and set another pin on the ground, which will come at C. The distance B C is double the error of adjustment. Correct the error by raising or lowering one end of the telescope axis by means of a small screw placed in the standard for that purpose. The amount the screw must be turned is determined only by repeated trials.

Fourth Adjustment.—To make the axis of the attached level of the

telescope parallel to the line of collimation.

Drive two stakes at equal distances from the instrument and in exactly opposite directions. Level the plate carefully, and clamp the telescope in a horizontal position, or as nearly so as possible. Sight to a rod placed alternately upon each stake, and have the stakes driven down until the rod reading is the same on both stakes. When this condition is reached, the heads of the stakes are at the same level. Then move the instrument beyond one stake and set it up so that it will be in line with both stakes. Level the plate again and elevate or depress the telescope so that, when a sight is taken to the rod held on first one stake and then on the other, the reading will be alike on both. In this position, the line of collimation is level, and the bubble in the level attached to the telescope should stand in the center of the bubble tube. If it does not, bring it to the center by turning the nuts at the ends of the tube, being careful at the same time to keep the telescope in the position that gives equal rod readings on both stakes.

THE CHAIN OR STEEL TAPE AND PINS.

The chain, which is generally 50 or 100 ft. long, should be made of annealed steel wire, each link exactly 1 ft. in length. The links should be so made as to reduce the liability to kink to a minimum. All joints should be brazed, and handles at each end of **D** shape, or modifications of **D** shape, should be

rovided. These handles should be attached to short links at each end, and the combined length of each of these should be attached to short links at each city, and the combined length of each of these short links and one handle should be exactly 1 ft. The handles should be attached to the short link in such a manner that the chain may be slightly lengthened or shortened by screwing up a nut at the handle. It should be divided every 10 ft. with a brass tag, on which either the number of points represents the number of tens from the front end, or the number of tens may be designated by figures stamped on the tags.

When a chain is purchased, one that has been warranted as "Correct, U.S. Standard," should be selected, and, before using it, it should be stretched on a level surface, care being taken that it is straight, and no kinks in it, and the extremities marked by some permanent mark. These marks can be used in the future to test the chain. It should be tested frequently, and the

length kept to the standard as marked when it was new.

In chaining, the chainmen should always remember the axiom that a straight line is the shortest distance between two points. Ordinarily, the chain should be held horizontally, and if either end is held above the ground, a plumb-bob and line should be used to mark the end of the chain on the ground. If used on a regular incline, the chain may be stretched along the vertical distances may either be calculated or found in the Traverse Table.

For accuracy, steel tapes are now almost exclusively used by the leading

mining engineers, on account of their greater accuracy as compared with

chains.

The steel tape is simply a ribbon of steel, on which are marked, by etching, or other means, the different graduations, which may be down to inches or tenths of a foot, or may be only every foot. It is wound on a reel, and may be any desired length up to 500 ft.

A well-made tape should not vary $\frac{1}{160}$ ft. in 100 ft., at any given standard temperature. The steel of the tape should not be too high in carbon, or it of temperature. will be brittle and liable to snap on a short bend, nor should it be of too soft

steel, or it will stretch when strongly pulled.

Careful gunsmiths can make and repair steel tapes with a high degree of accuracy, and fully as reasonably as the instrument makers. For outside work, tapes 1,000 ft. long have been made, but 500 ft. will be found as long as can well be used in a mine, owing to the lack of long sights, and to the increased weight of so long a tape. The average length is 300 ft. The 300 ft. are divided into 10-ft., 5-ft., 2-ft., or 1-ft. lengths, as desired, and the tenths and hundredths of a foot are read by means of a pocket tape or measuring pin. Sometimes there is an extra division before the zero mark, which is divided into feet and the first foot into tenths. With such a tape, a distance can be accurately measured to tenths, or even quite approximately to hundredths of a foot.

The ends are fitted with eyes on swivel-joints, to prevent straining by twisting. Handles of various forms have been devised to enable the tape to be stretched, or to clamp a broken end. Some parties use ordinary springs to prevent overstraining, and, in certain cases, spring scales are used, and the same degree of tension can be readily produced, and, in this way, the exact amount of sag can be calculated for any length, and the necessary correction made. To keep a mark on the tape for frequent reference, a clip (made by bending sharply on itself a piece of steel $\frac{1}{2}$ in. \times 3 in.) is slipped upon the tape, where it will remain unless subjected to considerable force. Reels for winding the tape are made of iron or wood, and vary greatly in size and shape.

When distances do not come at even feet, the fractional part of the foot should always be noted in tenths. Thus, 53 ft. and 6 in. should always

be noted as 53.5 ft.

Pins.—Pins should be from 15 to 18 in. long, made of tempered-steel wire, and should be pointed at one end, and turned with a ring for a handle. When using a 50-ft. chain, a set of pins should consist of eleven, one of which should be distinguished by some peculiar mark. This should be the last pin stuck by the front chainman. When all eleven pins have been stuck, the front chainman calls "Out!" and the back chainman comes forward and delivers him the ten pins that he has picked up, and he notes the "out." When giving the distance to the transitman, he counts his "outs," each of "out of the counter of 500 and add to their sum the number of fidees a denoted which consists of 500 ft., and adds to their sum the number of fifties as denoted by the pins in his possession, and the odd number of feet and fractional parts of a foot from the last pin to the front end of the chain.

The accuracy and value of a survey depend as much on the careful work of the chainmen as on anything else, and no one should be allowed to either drag or read the chain that is not intelligent enough to appreciate the

importance of extreme accuracy.

Pins are generally used in outside work, where they can be easily stuck to the ground, readily seen, and avoided, and the chances of their being disturbed are slight. Inside work generally contains so many chances of error in their use that they are usually abandoned in favor of other methods. If the sight be longer than the length of the tape, it is usual to drive a tack in a sill or a collar at a point intermediate between the stations, and take a measurement to the tack from each station, with the dip of the sights; or a tripod is set up in the line of sight, and the horizontal distance is measured from each station to the string of the plumb-bob under the tripod. The first method is the more accurate.

Plumb-Bob.—The plumb-bob takes the place of the transit rod in underground work, as the stations are usually in the roof, and strings are hung from them to furnish foresights and backsights. Plumb-bobs vary in weight and shape. At various times and in various countries where mine surveys have been made, the idea of sighting at a flame has been considered, and, from rough methods of setting a lamp on the floor on foresight and backsight. there have arisen various forms of plummet lamps. The idea is to continue the practice of sighting to a flame, but to make that flame exactly under the station, and to avoid the difficulty in sighting to the string of the plummet. The idea is good, but there has never been devised a plummet lamp that would be as free from error under all circumstances as the old-fashioned plummet, so that the majority of the best engineers have gone back to the plummet. The best plummet is the one that combines the least surface with plummet. The best plummet is the one that combines the least surface write the greatest weight, and the ordinary shapes used for outside work are the best for inside also. In a "windy" place, a hole can be dug in the ballast of the track and the "bob" let into this shelter where it will be unaffected by the air. The cord is best illuminated by placing a white paper or cardboard behind it and holding the lamp in front and to one side. The string shows as a dark line against a white ground, and there is less difficulty in finding it than when the light is placed exactly behind it, and in this way a careless man cannot hum the string by noting the flame against it. The careless man cannot burn the string by poking the flame against it. The white background will also illuminate the cross-hairs of the transit. The backsight "bob" can be made of lead, as there are no "centers" to be set by this man. A number of varieties have been made for the foresight, to aid him in "center setting"; but all get out of order easily. A quick man will do as good work with the old-style bob, and have none of the accidents common to the others. In general, it may be said that the instruments used for outside work will be sufficient for mine work also.

The clinometer, or slope level, is a valuable instrument for side-note work; but it is not accurate enough for a survey, and its place is taken by the vertical circle on the transit. There are two styles of clinometer, with a bubble and with a pendulum. The latter is the old-fashioned and more accurate German "Gradbogen" that is found on some old corps. The bubble variety is much more easily rendered worthless by the breaking of the bubble tube, and in general is not so accurate as the other style, which consists of a semicircular protractor cut out of thin brass and furnished with hooks at each end, that it can be hung on a stretched string so that the string will pass through the 0° and 180° points. The dip is read by a pendulum swung from the center of the circle. If made sufficiently large it will readily read to quarter degrees. By inclining the string parallel to the surface and hanging the clinometer, the dip will be obtained. A pocket instrument combining a compass and clinometer can be obtained from any dealer in

surveying instruments.

FIELD NOTES FOR AN OUTSIDE COMPASS SURVEY.

Call place of beginning Station 1.

Stations. Bearings. Distances.
1-2 N 35° E 270.0

At 1 + 37 ft. crossed small stream 3 ft. wide.

At 1 + 116 ft. = first side of road. At 1 + 131 ft. = second side of road.

At 1 + 137 ft. = blazed and painted pine tree, 3 ft. left, marked for a

"go by."

222.0

Station 2 is a stake at foot of white-oak tree, blazed and painted on four sides for corner. 2-3

N 831° E Station 3 is a stake-and-stones corner. S 57° E

3 + 64 ft. = center of small stream 2 ft. wide.

3 + 196 ft. = white oak "go by." 2 ft. right.

Station 4 = cut stone corner.4-5

S 3410 W 355.0 4 + 174 ft. = ledge of sandstone 10 ft. thick, dipping 27° south. 5-1 N 5610 W 323.0

5 + 274 ft. = ledge of sandstone 10 ft. thick, dipping 25° south (evidently continuation of same ledge as at 4 + 174).

Station 1 =place of beginning.

TRANSIT SURVEYING.

To Read an Angle.—The angle read may be included or deflected. set up at O with backsight at B and foresight at C, we shall find that there are two angles made by the line CO with the line BOA, namely the included angle BOC, and the deflected angle COA.

To Read the included Angle.—Set the zeros of vernier and graduated limb together accurately, and clamp the plates. Turn the telescope on the backsight, with the level bubble down,

and, when set, fasten lower clamp so as to fix both clamped plates to the tripod head. Loosen the upper clamp and turn the telescope to C and set accurately. The vernier will read, for example, "45° left angle."

To Read the Deflected Angle.—Arrange verniers as above and be sure and turn the telescope over on its axis till the bubble tube is up, and then take the backsight and fix lower clamp. Turn the telescope back (this is called "plunging" the telescope) and sight to foresight and fix as before. The vernier will read a "right angle of 135°." The sum

of included and deflected angles must always be 180°.

Note.—In making a survey by included angles, we must add or subtract 180° at each reading to have the vernier and compass agree; by deflected angles, they will agree without the above addition or subtraction, and the latter method is generally used.

TO MAKE A SURVEY WITH A TRANSIT.

By individual Angles.—Set vernier at zero of limb, plunge telescope, and, when set on backsight, loosen needle and read bearing of the line from backsight to set-up. Plunge telescope back and set on foresight and read both needle and vernier. The difference in needle readings should agree with the vernier reading within 15, as local attraction will affect the needle equally on both sights.

Note.—Any mass of iron or steel that may and will be moved during the readings of the needle, will affect the same and destroy the value of the needle as a check. The tape and other iron materials should not be moved

during the taking of angles.

By Continuous Vernier.—Set vernier at zero, unclamp compass needle, and when stationary, turn the north point of compass limb so as to coincide with the north point of the needle. Fix lower clamp, plunge telescope, and take backsight by loosening upper clamp. The vernier and needle should agree in giving the magnetic bearing of the line from backsight to set-up. Record this in note book; plunge telescope, and take foresight. Needle and vernier should agree as before. After making record, set up over foresight and take sight to station just left with telescope plunged, having first seen that the vernier reads exactly as it did on the last foresight, as a slip in carrying the transit from one station to another, which is not detected at the time, can never be checked afterwards when the final work is found to be in error. The foresight is taken as before. On every sight the needle and vernier should agree if there is no local attraction of the needle.

If we can see all the corners of a field that is to be surveyed from a central point, we can make the survey by setting up at that point, and, with one corner as a backsight, take all the other corners as foresights with but or set-up, and by measuring from this point to all of the corners; or we can set up at any corner and run a line of survey around the field. This latter method is called meandering. Both methods will give the same result when plotted; but the former is much quicker, as the boundaries of a tract are frequently overgrown with bushes that must be cleared to allow a sight while a central point can frequently be found that will allow a free sight to all the corners, and the distance can be measured by tape, or stadia. central point is nearer the corners than they are to one another, it follows that a shorter distance must be chained or cut in the case of a central set-up.

Outside surveys may be made for many purposes. It matters not what the purpose is, the work should be fully and accurately done, and the map should contain everything that will throw light upon the subject. If the outside work is to be connected with inside surveys, there are a number of points to be observed, and they will be given under the head of underground

work.

Meridians, or Base Lines.—The surveys must be based on some meridian, and started from some fixed point. There are four kinds of meridians, or "base lines."

First.—A line already on the ground, as one of the sides of the tract, is The subsequent work is referred to one or both ends of this taken as a base.

line, and all angles measured are taken as deviations from it.

Second.—A stone post is sunk in the ground, or, better, an iron plug is put into rock "in place"—that is, not loose rock, even if a large boulder—at such a distance from the works as to be beyond the influence of moving machinery, and a line of sight is taken to some permanent natural object, as far distant as can be clearly seen under adverse circumstances, as cloudy or dark weather. This line of sight is the base line, and the plug is the origin. No measurements of distance are needed. If no natural objects exist, a station is set up a a distance, so as to be as permanent as possible, and angles are turned from this to other points, so as to check any movement in it. Generally there are a number of tall chimneys, church spires, etc. to be found. While this is preferable to the first, it gives no method of check in underground work, and is seldom used.

Third.—The magnetic meridian is taken as the base line. The transit is set up over a plug, as just noted, and the subsequent work is as described under running continuous vernier. As the needle is subject to constant variation, this base line will afford a check underground only for a short time after the meridian is established, and all subsequent work can be checked only by applying the difference between the variation at the time of establishment, and at the time of making the survey. If the time of establishing the survey should be lost, the base line would become no better

than that noted in Case 2.

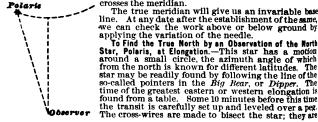
Fourth.—The true meridian is taken as a base. The true north and south line may be determined by observing the North Star, Polaris, or by observing the sun. The North Star does not lie exactly at the North Pole, but revolves about it in a small circle. There are two times in a day when it is exactly above or below the pole, and we take our sight at one of these times, when our transits do not have their graduated limbs made accurately enough to apply the proper angle for a sight at any other time. If we do not know the time when the star is crossing the meridian, we can find it by remembering that the fourth star in the handle of the "dipper" is in the same vertical plane with the north star 17 minutes before the latter

crosses the meridian. The true meridian will give us an invariable base

we can check the work above or below ground by

applying the variation of the needle.

To Find the True North by an Observation of the North
Star, Polaris, at Elongation.—This star has a motion around a small circle, the azimuth angle of which from the north is known for different latitudes. The star may be readily found by following the line of the so-called pointers in the Big Bear, or Dipper. time of the greatest eastern or western elongation is found from a table. Some 10 minutes before this time the transit is carefully set up and leveled over a peg. The cross-wires are made to bisect the star; they are



· illuminated by a light held under the reflector fastened on the object end of the telescope. The star is followed with the cross-wires until its motion toward the point of its greatest elongation ceases. The telescope is lowered vertically, care being taken, of course, not to move it horizontally, and a peg is set up on the line, say 300 ft. or 400 ft. distant. The next morning the correction is made for the star's azimuth. These corrections are different for different latitudes and different years. They are to be found in

the nautical almanac.

The method "by equal shadows" may be used with considerable accuracy, if we take a sufficiently long staff, or can obtain the shadows of a tall spire on a level surface. A vertical staff casts equal shadows at the

same time before and after noon. If we drive a stake at any time before noon, in the extremity of the shadow cast by such a staff, and measure its distance from the staff, we have

one leg of an angle. After noon we wait till the shadow becomes exactly as long as the distance measured, and drive a stake at the extremity of the shadow. A line bisecting the angle made by lines drawn from these two stakes to the staff will be in the meridian

Establishing a Meridian Line With the Solar Attachment.-The angle from the equator to the horizon of a place is its latitude; consequently, from the zenith to the pole is the colatitude, or 90° — latitude. The angular distance from the equator to the sun is the declination; consequently, from the sun to the pole is the polar dis-The angular distance from the horizon to the sun is the sun's

altitude; consequently, the zenith distance is the angular distance between

the sun and the zenith.

Adjustments of Burt's Solar Attachment.—After the instrument has been carefully leveled, the zero of the vernier of the solar is placed opposite the zero of the arc. The horizontal plates of the instrument are clamped, and the sun's image brought between the horizontal lines of either silver plate by any manipulation of the instrument and attachment possible, keeping the plates horizontal and the zero of the vernier opposite the zero on the arc. when the image is accurately between the horizontal lines, the arc is revolved so that the image falls on the other plate; this must be done rapidly, as the sun's image moves. If it does not fall between the lines, half the error is corrected by the tangent screw of the solar and half by the tangent screw of the telescope. The operation is repeated until the sun's image falls between the lines of the second plate, after a revolution of the arc, it having been made to fall between the lines of the first, as described. Near noon is a good time to make this adjustment, as the sun's apparent motion is not so rapid. The zero of the vernier is now brought opposite to the zero of the arc by loosening the screws that fasten the vernier, and sliding it as may be necessary. It is often difficult to make the zeros come exactly opposite each other, as the vernier plate is apt to move slightly when the screws are tightened again. The second adjustment is to make the tops of the rectangular blocks of the solar attachment level, when the telescope is level and the arc of the solar is set at zero. Level the transit carefully, as before described, set the solar at zero and place the level, furnished with the solar, across the tops of the blocks. If the bubble comes to the center of the tube, no correction is needed; if it does not, correct the error by turning the screws under the hour circle, care being taken in this as in all other movements of these adjusting screws, to leave them tight after the correction. Revolve 180° and correct again if necessary. Placing the blocks 90° horizontally from their first position, go through the same operation as described until in all positions the bubble remains centered.

To Use the Solar.—Before this instrument can be used at any given place, it is necessary to set off upon its arcs both the declination of the sun, as affected by its refraction for the given day and hour, and the latitude of the

place where the observation is made.

The declination of the sun as given in the ephemeris of the nautical almanac from year to year, is calculated for apparent noon at Greenwich, England. To determine it for any other hour at a place in the United States, reference must be had, not only to the difference of time arising from the difference of longitude, but also to the change of declination during that time.

The longitude of the place, and therefore its difference in time, if not given directly in the tables of the almanac, can be ascertained very nearly by reference to that of other places given which are situated on, or very nearly

on, the same meridian.

It is the practice of surveyors in states east of the Mississippi to allow a difference of 6 hours for the difference in longitude, calling the declination given in the almanac for 12 m. that of 6 A.M. at the place of observation. Beyond the meridian of Santa Fé, the allowance would be about 7 hours; and in California, Oregon, and Washington, about 8 hours. Having thus the difference of time, we very readily obtain the declination for a certain hour in the morning, which would be earlier or later as the longitude was greater or later as the longitude was greater or later as the same as that of expenses them. greater or less, and the same as that of apparent noon at Greenwich on the given day. Thus, suppose the observation made at a place 5 hours later than Greenwich, then the declination given in the almanac for the given day at noon, affected by the refraction, would be the declination at the place of observation for 7 A.M. This give us the starting point.

To obtain the declination for the other hours of the day, take from the almanac the declination for apparent noon of the given day, and, as the declination is increasing or decreasing, add to, or subtract from, the declination is increasing or decreasing, add to, or subtract from, the declination of the first hour the difference of one hour as given in the ephemeris, that will give, when affected by the refraction, the declination of the

that will give, when anected by the retraction, the declination of the succeeding hour. Proceed in like manner to make a table of the declinations for every hour of the day.

To Find the True North With the Burt Solar.—Find from an ephemeris or nautical almanac the sun declination for noon of the day of observation at Greenwich. Find the declination for the hour of observation at the place of observation by first figuring what time it is at the place of observation when it is noon at Greenwich. If the place of observation is west of Greenwich, it will be earlier there; if east, later, and in either case the difference will be one hour for every 15° of longitude. If the place is west, subtract the hour just found as described from the hour of the observation, and multiply the hourly difference, also taken from the ephemeris, by the remainder. the declination is increasing from the equator either north or south, add this product to it; if decreasing, subtract it. A table of refractions is given in the ephemeris for the different latitudes and the different hours of the This refraction is to be added if the declination is north, and subtracted if the declination is south. Having thus ascertained the declina-tion, lay it off on the declination arc. Set the colatitude of the place off on the vertical arc after having leveled the instrument carefully with clamped horizontal plates at zero. Always in solar observations it is well to level by means of the upper telescope bubble. Now, revolve the horizontal plates still clamped, and also the declination arc, around its polar axis until the sun's image is exactly between the horizontal lines of the silver plates. When the sun's image is between these lines, the object end of the telescope will be pointing north.

To Take the Latitude With Burt's Solar .- A few minutes before apparent noon clamp the plates at zero, level the instrument carefully, and set the zero of the vernier opposite the zero of the vertical arc. Lay off the declination, corrected for noon at the place of observation and for refraction, on the declination arc, and set the time mark on the declination arc opposite XII on the hour dial. Bring the sun's image between the horizontal lines of the silver plate by moving the plates horizontally and the telescope vertically, clamp both plates and telescope and follow with the tangent movements the rising sun. Be careful to stop when the sun ceases to mount. For a moment before apparent noon there is no perceptible motion of the image. The reading on the vertical arc is the colatitude of the place.

The colatitude should never be taken this way for direct-sight calcula-

tions, for while it satisfies the automatic solution of the true north, it may not be accurate, and the latitude needed for direct-sight calculation should be true to within a minute. With the Burt solar there is at times what is called a false image to guard against, an image that comes between the lines of the silver plates when the object end of the telescope is not pointing morth. If the time be observed on the hour dial, or the magnetic north be noticed, no error need ever occur on this score, for with the false image the

time will be out considerably and also the magnetic variation.

General Remarks.—With the base line located and the survey made, we see,

the survey made, we see, whether it be correct in distance or angle. If it be in error, see if the error can be located (as will be shown under plotting), and if it can be found, run those parts over again; if not, repeat the whole survey. Shoving the work, as it is called, or "doctoring" it so that it will close, is the poorest practice that an engineer can engage in, as all subsequent work that depends on a doctored survey must be doctored to fit the faulty work—even if it be right in itself. Every engineer should be able to swear—not that he "thinks the survey is accurate," but "that he knows it to be so," if he should be called as a witness in court. One of the causes of inaccuracy is haste.

To make a complete map, the engineer should first make a survey around the tract to be worked, locating all the prominent physical features and improvements. If he can do so, he should make a topographical map of the tract at once; but, if time is limited, by running the vertical as well as the horizontal angle, he can carry the tidal elevation or the elevation above some assumed datum, to every station, and mark it on the map at that point. Then as he makes subsequent surveys, he can gradually get data enough to make a fairly complete topographical map in course of time. Every ledge of rock in place should be located, and the amount and direction of its dip, as well as the character of the rock, should be marked neatly on the map. The streams of water on the tract should be regarded as of primary impor-

tance, and should be located with exactness.

With a true meridian base line we can connect maps made at different places with little trouble. This is especially useful with adjoining mines connected at but one point. Having made the survey and come home, we must examine all the apparatus and see if the instruments are out of adjust-ment, as such a fact will prevent our bothering over work that will not close. It will assure us, also, that we can start out at a moment's notice with no thought of the adjustment of our tools. A famous wit said that the proper time to strop a razor was just after you had used it, as you then knew how much it needed it. The same will apply to surveying instruments and tools—especially for underground work. Here the lamp smoke, powder gases, mine dust, paint smears, acid water from "droppers," and the other abominations incident to underground surveying, especially in a coal mine, will so cover the tools that they would be useless if left uncleaned half a dozen times. As soon as the corps comes back from the mine, and before the clothes are changed, the tape must be stretched, tested, wiped, and oiled. It can be inspected to see if marks are too much worn, or it stands in need of mending, the marking pot is cleared of "muck," and fresh white paint is mixed, if the corps is going out in 24 hours; the plummets will have their strings overhauled and freed from knots; hatchets will be sharpened, and strings overnauted and freed from knots; natchets will be snarpened, and axes ground, pouches overhauled, and a supply of tacks or "spads" taken. Then the transitman changes his clothes and sets up the transit, wipes it with a cloth wet with alcohol, so as to remove dirt, oil, and paint. If water has gotten between the graduated limb and compass box, the verniers must be uncovered and the whole wiped dry. If the sulphureted hydrogen from the powder smoke has tarnished the silver surfaces of any of the graduated circles it must be removed with whiting. Alcohol should be always used. circles, it must be removed with whiting. Alcohol should be always used instead of water, as it will quickly evaporate and leave the parts dry. The telescope glasses are then wiped with soft chamois leather, and the instrument is tested for want of adjustment before putting it away in its box. When going to and from work, the transit should not be carried on the transit head, or the spindle will become sprung. Nor should it be carried with the arm crooked under the telescope, as the weight comes on the axis, and that soon gets sprung so that all the adjusting in the world will not make it work right. When carried in the hand, it should be reversed and the hand slipped under the compass plate and brought over so as to clamp In this way there will be no strain on any part. both plates. In case of a "fall" in the mine, remember that the transit is the baby to be protected, and stand a few bumps to save a strained or broken instrument, that will

and the work for some time.

Pletting.—A "plot" is not only a piece of ground with bodies of water, roads, vegetation, etc. upon it, but refers also to the map of the same drawn to a given scale, and showing all of the above natural features. Plotting is

the making of such a map from notes of a survey, and may or may not require the permanent placing of the stations on the map, by which the survey is made. In underground work, the exact location and the retention of those stations is a matter of the first importance, and is secondary only to the exact plotting of the side notes. The scale of the plot is generally as large as will show the points of interest in the property; but in Pennsylvania, the maps for coal mines must be drawn to a scale of 100 ft. to an inch. There are two methods of plotting: by protractor, and by coordinates. When the scale is sufficiently large, it is a matter of little choice which method is used if the work be carefully done with exact instruments. which method is used, if the work be carefully done with exact instruments; but with small scales—100 ft. or above, to the inch—we should use the method by coordinates. With the latter scale, the prick of a pin on the paper will represent a foot square, or a circle slightly larger than a foot in diameter. If the next station is to be located from the pin prick of the first, and that is exactly located, we may not hit the exact center of that small indentation. In fact, the chances are greatly against our doing so, and the location of the second station will probably be in error. If we have a bad habit of placing the protractor or the straightedge against one side of the pin pricks, or pencil marks, when the scale is large, we shall constantly be introducing a "personal error," as it is called, and the sum of all the errors made at each of 100 stations will bring our final point very much out On this account, and from the fact that no protractor that is of the way. movable can be used without the chances of slipping while the angle is read or marked, has led all careful engineers to abandon its use in favor of the method by coordinates. When the scale is from 1 to 25 ft. to an Inch, the errors are small enough to make little chances of variation in a close of ten or twelve stations; when the survey is of short sights from a main line to points where no further work is to be done, the protractor will afford a quick method of plotting.

There is a chance of error in both methods that must be noted here, where the survey is not completed at one time. If the map be made in a day or two, and will never be extended by subsequent work, there will be no chance of error from a change in the paper on which it is made, due to moisture or dryness; but if the map be made on a series of very damp days, or a series of very dry ones, a change in the weather to the other extreme will swell or shrink the map. The general tendency in a large mine map that is frequently used, and is rolled and unrolled every day for five or six years, is to stretching, so that there will be a variation of from 1 to 5 ft. in 1,000. If we extend a recent survey on such a map, we are plotting it to a different scale to that assumed by the map under the conditions above The paper on which the map is to be drawn should be tacked down to the table or board, and should be covered with squares each exactly 10 in. The sides of these squares should be the meridians, or north or south lines, and the tops and bottoms should run due east and west. Mark the first station on the paper, set your parallel ruler or T square on the meridian nearest it, and with the protractor produce the course to the next station. Measure the distance with a scale, and proceed in this manner to plot all the courses, using each time the meridian nearest the station the course is taken from. After all the stations have been plotted, fill in the side notes, marking everything on the map with great care and neatness. Always use the horizontal distances. All surveys should be traversed and all plotting should be either checked by the traversing, or the principal stations should be plotted by use of the traverse. For a large mine map that will be in use many years, muslinbacked egg-shell paper must be used. It comes in a long roll, and any

reasonable length, and a width up to 6 ft. can be obtained.

To Calculate the Vertical Distances.—When making the survey, read the vertical angles to all stations. If the angle is one of depression, note it with a minus sign (—) preceding it. If it is an angle of elevation, precede it with a plus sign (+). These will show whether the vertical distance is to be added to, or subtracted from, the height of the preceding station. Having the horizontal distance and the vertical angle:

Having the horizontal distance and the vertical angle: Distance × tangent of vertical angle = vertical distance. Having the pitch distance and vertical angle:

Distance \times sine of vertical angle = vertical distance.

To Calculate the Horizontal Distance, or Latitude.—Pitch distance \times cosine of vertical angle = horizontal distance.

Vertical height, or departure + sine of vertical angle = horizontal distance.

To Calculate the Pitch Distance.—Horizontal distance + cosine of bearing, or multiplied by secant of bearing = pitch distance.

Vertical distance + sine of vertical angle, or multiplied by cosecant of

bearing = pitch distance.

To Calculate the Vertical Angle.—The horizontal distance ÷ the pitch distance = cosine of vertical angle.

Vertical distance + pitch distance = sine of vertical angle.

Vertical distance \div horizontal distance = tangent of vertical angle.

Note.—Whenever sines, cosines, tangents, etc. are here named, they mean

the natural sines, etc. of the angle.

Plotting by Coordinates.—In describing the establishment of a meridian and a fixed point, we made the latter a stone post, or iron plug sunk in solid rock. This point is called the origin of coordinates. We have the principal meridian passing through this point in an exact north and south direction, and a secondary meridian or base line passing through this point at right angles to the first, or in an exact east and west line. Any point we may select on the map will be a certain distance north or south, and east or west of the origin. The lines drawn from this point at right angles to the two base lines just given are called the coordinates of that point, and we can plot the point when they are given. For example, the coordinates of Station 24 are North 345.67, and East 890.12. We measure 890.12 ft. east of the origin on the secondary meridian and, from this point, measure 345.67 ft. north to the point desired; or we can measure first on the primary meridian to the north and then turn off a right angle to the east and reach the same point. In any event we plot the position of each station independently of all the others, and any error in locating one is not carried to the next. When two stations are plotted, the distance between them on the map should be exactly what we found for their horizontal distance on the ground. This check shows whether our plotting is correct. This is also called traversing a survey if the meridian be north and south, and in books on surveying there are printed traverse tables, which are accurate within certain limits, but not so accurate as the tables of coordinates published separately, as the latter are carried to a greater number of decimals. Gurdon's Traverse Tables will enable you to find, without calculation, the coordinates for a distance of 12 miles with a chance of error of only half an inch, which is much more accurate than the graduation of the instruments with which the work was done.

With a north and south meridian, the point from which we begin to measure angles—the zero point—is the north point, and the angles are read for continuous vernier in the direction of the hands of a watch. The sines of angles are eastings and westings, and the cosines are northings and

southings.

To Traverse a Survey.—To traverse a survey, means to determine by calculation how far north or south and east or west any station may be from another, the location of which is fixed. To do this, all distances must be another, the location or which is fixed. To do this, all distances must be either measured horizontally, or calculated to horizontal distances. The horizontal angles, or courses, must be either read as quadrant courses, or reduced from azimuth to quadrant courses. An azimuth course is one that is read on the transit which is graduated from 0° to 360°. A quadrant course is one read in the quadrant of the circle, as 8 67° W, N 43° E, etc.

Latitude means distance north or south, and is determined by the first interest of the circle of the circl

initial of the recorded course. Thus, if a course is S 67° W, the latitude is

south; if N 43° E, the latitude is north.

Departure means distance east or west, and is determined by the last Thus, if a course is S 67° W, the departure is initial of the recorded course. west; if N 43° E, the departure is east.

The latitude = distance \times cosine of bearing.

The departure = distance × sine of bearing.

If the survey is a continuous one around a tract, and ending at the place of beginning, the sum of the northings should equal the sum of the southings, and the sum of the eastings should equal the sum of the westings. Or, in other words, the sum of all the latitudes north, should equal the sum of all the latitudes south; and the sum of all the departures east, should equal the sum of all the departures west. It is evident that by coming back to the place of beginning the surveyor has traveled the same distance north as he has south, and the same distance east as he has west.

The most accurate way to construct a map is to traverse the survey and place all stations on it by the traversed distances, or to at least put a number of the principal stations on the map by the traversed distances, and

use the protractor to plot only the intermediate stations. As the origin of use the protractor to plot only the intermediate stations. As the origin of the survey is at the fixed point just mentioned, we must make a rough pencil sketch to find the approximate location of this point from the boundaries of the property, and the general trend of the property itself. This will show us the place to put the origin upon the paper so that all of the property can be placed on the map, and leave about the same amount of margin on all sides. It will also show us the direction the north and south line must take on the paper. When this is settled, mark the origin by a needle point, and lay the straightedge across it in the direction to be taken by the principal meridian, and draw the meridian with a quite hard pencil brought to a very fine point. Then lay off on both sides of the origin distances of 5 in., and mark them with needle points. These must be so accurately located that there will not be an error of one hundredt of an inch in them, or one foot in five hundred. At the point where we can get inch in them, or one foot in five hundred. At the point where we can get the longest line on the paper at right angles to the principal meridian, lay off points for a right angle accurately on each side of the meridian, and draw through the three points, by means of the straightedge, a line parallel to the secondary meridian and divide this accurately into 5" distances as before. Through each of the points thus marked, draw lines at right angles to the lines already drawn, until the paper is accurately divided into square 5 in. on a side, and none of them with an error of one five-hundredth. Beginning with the origin, mark the extremities of the lines passing through it zero. All distances to the east or upon the right side of the north and south zero line are marked + with respect to that line; those to the left are marked —. All distances above the east and west zero line are marked + with respect to that line, and all distances below it - . If the coordinates of a point are N 234, and E 2,468.78, we need not measure the whole east distance from the origin, but start from the north and south line marked + 20. With 5" squares, a 6" scale will be sufficiently long for plotting. To illustrate plotting by use of the traversed distances, we will use the following

Stations.	Quadrant Courses.	Distances.	Latitudes.		Departures.		Totals.			
			N	s	Е	w	N	s	E	W
1-2 2-3 3-4 4-5	N 35° E N 83° 30′ E S 57° E S 34° 15′ W	270 129 222 355	221 15	121 293	155 128 186	200	221 236 115	178	155 283 469 269	
			236	414	469	200				

The foregoing table, calculated according to formula for latitudes and departures, shows that Station 2 is 221 ft. north and 155 ft. east of Station 1; and that Station 5 is 178 ft. south and 269 ft. east of Station 1.

These stations, or Stations 3 and 4, or all, may be placed on the map by

simply making the two measurements for each station.

To Find the Area of a Tract of Land.—If a regular polygon, find the area by the rule given under the head of "Mensuration" for polygons of the same number of sides. If an irregular polygon, divide it into triangles and calculate the area of each triangle; the sum of these areas will be the area of the tract. If the tract is an irregular polygon in shape, the map should be made on as large a scale as possible, and the distances should be measured with the greatest care, owing to liability to error through very slight inaccuracies of measurement.

To Find the Contents of a Seam of Coal Under a Tract.—If the seam lies flat. multiply the area of the tract in square feet by the thickness of the seam in The product will be the cubical contents of the seam in feet. seam is an inclined one, find its area by measuring the width of the tract on its line of pitch, and find the distance on the pitch of the seam by dividing . the horizontal distance measured by the cosine of the augle of inclination. This will give you the pitch distance. Multiply the pitch distance by the length of the tract, and you will have the area of the seam. This multiplied by its thickness will give the contents.

LEVELING.

Instruments.—But two instruments are used—the level and a leveling rod. The level consists of a telescope to which is fitted, on the under side, a long level tube. The telescope rests in a ¥ at each end of a revolving bar, which is attached to a tripod head very similar to that used for a transit. The telescope is similar to the telescope of a transit. The leveling rod is merely a straight bar of wood, 6 ft. or more in length, divided into feet and tenths of a foot. A target divided into four equal parts by two lines one parallel with the staff, and the other at right angles to it, and painted red and white, so as to make it prominent at a distance, slides on the rod and is provided with a clamp screw. The center of the target is cut out and a vernier, graduated decimally, is set in, which enables the rodman to read as close as who of a foot.

close as 7050 of a foot. If a long rod is required, it is made of two sliding bars, which, when closed, are similar to a single rod, as described above. When used at points where it is necessary to shove the target to a greater height than 6 or 6 ft. the target is clamped at the highest graduation on the front of the rod, and the rod is extended by pushing up the back part, which carries the target with it. The readings, in this case, are made either from the vernier on a graduated side, or a vernier on the back. The rodman must always hold his

rod perfectly plumb or perpendicular.

To Adjust the Level.—The proper care and adjustment of the level is of great importance. A very slight error in adjustment will completely destroy the

utility of any work done.

To Adjust the line of Collimation.—Set the tripod firmly, remove the V pins from the clips, so as to allow the telescope to turn freely, clamp the instrument to the tripod head, and, by the leveling and tangent screws, bring either of the wires upon a clearly marked edge of some object, distant from 100 ft. to 500 ft.

Then with the hand, carefully turn the telescope half way around, so that

the same wire is compared with the object assumed.

Should it be found above or below, bring it half way back by moving the capstan-headed screws at right angles to it, remembering always the inverting property of the eyepiece; now bring the wire again upon the object, and repeat the first operation until it will reverse correctly. Proceed in the same manner with the other wire until the adjustment is completed. Should both wires be much out, it will be well to bring them nearly correct before either is entirely adjusted.

To Adjust the Level Bubble.—Clamp the instrument over either pair of

leveling screws, and bring the bubble into the center of the tube.

Now turn the telescope in the wyes, so as to bring the level tube on either side of the center of the bar. Should the bubble run to the end, it would show that the vertical plane, passing through the center of the bubble, was not parallel to that drawn through the axis of the telescope rings. To rectify the error, bring it by estimation half way back, with the capstanheaded screws, which are set in either side of the level holder, placed usually at the object end of the tube. Again bring the level tube over the center of the bar, and adjust the bubble in the center, turn the level to either side, and, if necessary, repeat the correction until the bubble will keep its position, when the tube is turned half an inch or more to either side of the center of the bar. The necessity for this operation arises from the fact that when the telescope is reversed, end for end, in the wyes in the other and principal adjustment of the bubble, we are not certain of placing the level tube in the same vertical plane, and, therefore, it would be almost impossible to effect the adjustment without a lateral correction.

impossible to effect the adjustment without a lateral without properties. We proceed to make the level tube parallel with the bearings of the V rings. To do this, bring the bubble into the center with the leveling screws, and then, without jarring the instrument, take the telescope out of the wyes and reverse it end for end. Should the bubble run to either end, lower that end, or, what is equivalent, raise the other by turning the small adjusting nuts, on one end of the level, until, by estimation, half the correction is made; again bring the bubble into the center and repeat the whole operation, until the reversion can be made without causing any change in the bubble. It would be well to test the lateral adjustment, and make such correction as may be necessary in that, before the horizontal adjustment is entirely

completed.

To Adjust the Wyes.—Having effected the previous adjustments, it remains now to describe that of the wyes, or, more precisely, that which brings the level into a position at right angles to the vertical axis, so that the bubble will remain in the center during an entire revolution of the instrument. To do this, bring the level tube directly over the center of the bar, and clamp the telescope firmly in the wyes, placing it as before, over two of the leveling screws, unclamp the socket, level the bubble, and turn the instrument half way around, so that the level bar may occupy the same position with respect to the leveling screws beneath. Should the bubble run to either end, bring it half way back by the V nuts on either end of the bar; now move the telescope over the other set of leveling screws, bring the bubble again into the center, and proceed precisely as above described, changing to each pair of screws, successively, until the adjustment is very nearly perfected, when it may be completed over a single pair.

The object of this approximate adjustment is to bring the upper parallel plate of the tripod head into a position as nearly horizontal as possible, in order that no essential error may arise, in case the level, when reversed, is not brought precisely to its former situation. When the level has been thus completely adjusted, if the instrument is properly made, and the sockets well fitted to each other and the tripod head, the bubble will reverse over each pair of screws in any position. Should the engineer be unable to make it perform correctly, he should examine the outside socket carefully to see that it sets securely in the main socket, and also notice that the clamp does not bear upon the ring that it encircles. When these are correct, and the error is still manifested, it will probably be in the imperfection of the

interior spindle.

After the adjustments of the level have been effected, and the bubble remains in the center in any position of the socket, the engineer should carefully turn the telescope in the wyes, and sighting upon the end of the level, which has the horizontal adjustments along each side of the wye, make the tube as nearly vertical as possible. When this has been secured, he may observe, through the telescope, the vertical edge of a building, noticing if the vertical hair is parallel to it; if not, he should losen two of the cross-wire screws at right angles to each other, and with the hand on these, turn the ring inside, until the hair is made vertical; the line of collimation must then be corrected again, and the adjustments of the level will

be complete.

To Use the Level.—When using the instrument, the legs must be set firmly into the ground, and neither the hands nor person of the operator be allowed to touch them; the bubble should then be brought over each pair of leveling screws successively, and leveled in each position, any correction being made in the adjustments that may appear necessary. Care should be taken to bring the wires precisely in focus, and the object distinctly in view, so that all errors of parallax may be avoided.

This error is seen when the eye of an observer is moved to either side of the center of the eyepiece of a telescope, in which the foci of the object and eyeglasses are not brought precisely upon the cross-wires and object; in such a case the wires will appear to move over the surface, and the observation will be liable to inaccuracy. In all instances the wires and object should be brought into view so perfectly that the spider lines will appear to be fastened to the surface, and will remain in that position however the eye is moved.

If the socket of the instrument becomes so firmly set in the tripod head as to be difficult of removal in the ordinary way, the engineer should place the palm of his hand under the wye nuts at each end of the bar, and give a sudden upward shock to the bar, taking care also to hold his hands so as to

grasp it the moment it is free.

Field Work.—If the survey has been carefully made and vertical angles taken at every sight, leveling will be necessary only in cases where extreme accuracy in regard to vertical heights is necessary. In most cases of practical work at collieries, particularly in determining thickness of strata, general rise or fall of an inside road, etc., the elevations calculated by the use of the vertical angle will be close enough, but there are frequently instances when leveling must be done to insure success in certain work. this connection it is well to state that if the transit telescope is supplied with a long level tube, and it is, as a whole, in first-class adjustment, levels can be successfully run with it, if the transitman uses due care. Having his instrument in proper adjustment and his note book ruled, the levelman is ready to proceed with the work.

The rodman holds the rod on the starting point, the elevation of which is either known or assumed. The levelman sets up his instrument somewhere in the direction in which he is going, but not necessarily, or usually, in the precise line. He then sights to the rod and notes the reading as a backsight or + (plus) sight, entering it in the proper column of his note book, and adding it to the elevation of the starting point as the "height of instrument." The rodman then goes ahead about the same distance, sets his rod on some well defined and solid point, and the levelman sights again to the target, which the rodman moves up or down the rod till it is exactly bisected by the horizontal cross-hair in the telescope, as he did when giving the backsight subtracted from the height of instrument gives the elevation of the second station. The rodman holds this latter point, and the levelman goes ahead any convenient distance, backsights to the rod, and proceeds as before. In this case we have assumed that levels are only being taken between regular stations or two extreme points.

If a number of points in close proximity to each other are to be taken, the rodman, after giving the backsight, holds his rod at each point desired. The readings of any number in convenient sighting distance are taken and recorded as foresights, and any descriptive notes are made in the column of remarks. These are each subtracted from the height of instrument, and the elevation found is noted in column headed elevation. After all the intermediate points are taken, the rodman goes ahead to some well-defined point, which is called a "turning point" (T. P.) in the notes. The elevation of this is found and recorded. The rodman remains at this point until the levelman goes ahead, sets up and takes a backsight. This backsight reading, added to the elevation of the turning point, gives a new height of instrument from which to subtract new foresights, and thus obtain the elevation of the

next set of points sighted to.

When running levels over a long line, the levelman should set frequent "bench marks." These are any permanent well-defined marks that can be readily found and identified at any future time. By leveling to them he has secured the elevation of points from which to start any subsequent levels that may be necessary. A good bench mark can always be made on the side or root of a large tree or stump by chopping it away so as to leave a wedge-shaped projection with the point up. Drive a nail in the highest point of this, to mark where the rod was held, and blaze the tree or stump above the bench mark. In this blaze, either cut or paint the number of the bench mark, which should, of course, correspond with the number in the note book. In the mines, prominent frogs or castings in the main roads, if permanent, make good bench marks.

LEVEL NOTES.

Station.	B. S.	F. S.	H. Inst.	Elev.	Remarks.
1	3.412		103,412	100.	Assumed elevation of Station 1.
2	3.412	4.082	100,412	99.33	Station 2 of survey. See page
		6.791		96.621	Sight taken to ground at N. E. cor. John Smith's house.
3 = T. P.	11.698	4.862	110.248	98.55	Station 3 of survey noted above.
B. M. 1	11.096	9.817 6.311	110.246	100.431 103.937	Station 4 of survey noted above. B. M. 1 is on north side of large white oak.
5		6.427		103.821	Station 5 of survey noted above.

In underground leveling, extreme care must be observed to record the algebraic signs of the readings, which show whether the level od was held in its usual position, indicated by a + sign or the absence of any sign, or upside down, indicated by the — sign.

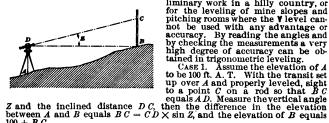
PROOF OF CALCULATIONS.—The calculations are proven by adding together the backsights and also the foresights taken to turning points and last

station. Their difference equals the difference of level between the starting point and last station. Thus:

Foresights.	Backsights.	
4.862	3.412	
6.427	11.698	
11.289	15,110	
	11.289	
	3.821 = 103.821 - 100.0	or 3.821.

TRIGONOMETRIC LEVELING.

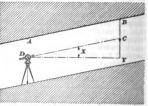
This method determines the difference in elevation between two points from the measurement of the distance between the points, and from the ing with a V level, it is much more rapid and is especially adapted for pre-liminary work in a hilly country, or for the leveling of mine slopes and pitching rooms where the V level can-



not be used with any advantage or accuracy. By reading the angles and by checking the measurements a very high degree of accuracy can be ob-

100 + B C.

CASE 2. Assume the elevation of station A in the roof of a mine to be Then with the transit 100 ft. A.T. set up directly under A and properly leveled sight to a point C upon the plumb-line suspended from the station B, measure the vertical angle X, inclined distance D C, and roof distance B C. From this, the distance C Y = D C \times sin X. The elevation of B is then found as follows: The elevation of B = the elevation of A - AD + $(DC \times \sin X) + BC$.



There are many modifications of this simple method, but from the above diagrams the most complex modifications can be worked out.

TRIGONOMETRIC LEVEL NOTES.

Station.	Vertical	Inclined	Vertical	Height of	Roof	Eleva-
	Angle.	Distance.	Distance.	Instrument.	Distance.	tion.
$A - B \\ B - C \\ C - D \\ D - E$	+5° +2° -3° -4°	100 100 100 100	+8.72 +3.49 -5.23 -6.98	2' 3' 4' 2'	3' 2' 3' 1'	+100 109.72 114.21 107.99 100.01

UNDERGROUND SURVEYING.

There are a number of variations in the foregoing practice that are caused by the entirely different set of conditions in underground work. These have been grouped together for convenience of reference.

The Establishment of Stations.—As this is the most important duty of an engineer in surface work, so it takes the first place in work underground, as the accuracy of the work depends on the location of the stations, while its pidity depends on using the fewest number consistent with completeness. It also stands to reason that the fewer the number of stations, the fewer the chances of error. In underground work, stations should be located under the conditions of permanence, freedom from destroying agencies, and ease of Temporary stations for a single sight need not fill all these require-We establish them generally in the roof of the mine-less frequently in the floor. In the former case we must establish a "center" before each set-up of the transit, and thus underground differs from surface work. first surveys were made with lamps set on the floor, sighted to, and then set over. Permanence was secured by driving iron nails or tacks in the sills of the track or sets of timber. As acid water soon destroyed these, they were followed by copper tacks or brads, and all were witnessed by notches cut on both sides of the sill, as in outside work, and by a vertical paint mark on the solid wall, with the number of the station. This method is faulty, as the tracks in crooked gangways are seldom placed where one can get the longest sight, and, as they are the traveling ways, the stations run the chance of being knocked out by passing men or mules, and the whole track, on a curved incline, is generally sprung by every loaded trip. As the sights must be as long as carefulness of work will allow, we put them generally in the roof, as that offers the greatest area for a choice, and is not under foot. Any settling of the roof so as to affect the accuracy of the station would be equally effective in destroying the accuracy of a station in the floor. We therefore choose places that will be least affected by subsequent work, and put the stations in collars, lids or wedges of props, in the props themselves, when they have incline sufficient to allow the transit to be set under them, or in the roof itself. Wherever set, they should not project far from the surface, and thus be liable to be brushed away in a low gangway by cars with topping higher than usual, or knocked away by flying fragments from a shoi, if near the working faces. Top stations have a mark about them to call attention to It is generally a circle, unless there are other corps at work their location. in the same mine that use the circle, and the stations of the two surveys would be confused if marked alike. In this case a corps selects some easily made figure, as a triangle, square, etc. If two surveys use the same station, the mark of the second survey is placed around that of the first, and the "Remarks" give "Station No. 234 of L. & S. corps," etc.

Kinds of Stations.—The simplest top station is a shallow conical hole, made with the point of the foresight man's hatchet, which is dug into the top rock and rotated, and is called by some a jigger station. Corps using these entirely have a jigger consisting of a steel-pointed extension rod, with an offset holding a paint brush. The rod is long enough to allow the point to be driven into the roof at any height, and its rotation marks a circle with the brush. which is also used to mark the number beside it. Centers are set under such stations and sights are given by another tool—also called a jigger. This is an extension rod, beyond the upper end of which projects a piece of sheet iron shaped like an isosceles triangle, with the upper and smaller angle cut off so as to form an end one-quarter of an inch broad, and in this end is cut a

U-shaped groove.

U-shaped groove.

The sights are given and the "centers" set by putting the plummet cord in this groove, and placing the end in the "jigger hole" in the roof. The cord must be more than twice the length of the section of the place, as it must be held in the hand, run over the jigger notch, and hang vertically to the plummet, which must come to the floor when the stations are set. The mod and cord are held in the left hand, and the right is free to steady the "bob," give sight, or set the center. The advantage of this method lies in the print the stations are set. the quickness with which the centers are set and the sights given, and the ease with which the highest stations are reached. The disadvantages are the impossibility of making the jigger hole perfectly conical, so that the jigger can be set in the same place on two successive sights, and the plummet cord will hang exactly in the same place.

Second.—Common shingle nails are driven into collars, or cracks in the roof. The end of the plummet line is noosed and put over the head. causes an eccentric hanging of the plummet that may cause an error in backright and foresight of the width of the nail head, which will be quite appreciable in a short sight. To do away with this error, a variety of nails (called spads, spuds, etc.) are made of iron or copper. Iron will not corrode in dry mines,

and is much cheaper. The simplest is made by hammering out the head of a horseshoe or mule-shoe nail, punching a hole in the flattened head for inserting the cord, and cutting off the point, so as to make the finished spad an inch long. This will bring the head near the surface without having to drill too deep a hole, and will make them unit for lamp picks, as they are very handy for such purposes, and thousands have been pulled out to this end. Any blacksmith can furnish them for less than I cent each. They are driven broadside to the line of sight, or they will be liable to the same objection as the shingle nail. To remove all chance of eccentricity, a form is made with a shoulder in which a hole is drilled parallel to the length of the nail. The practice of using staples for stations is antiquated—though given in the last editions of some modern textbooks—and should never be used where accuracy is required.

Third.—All these varieties of spads are driven into a crack of the roof; but such stations cannot be called permanent, as the same force that made the crack will tend to open it and let the nail drop. Even if this does not happen, we shall have the water in a wet mine coming in by these cracks, and rotting the nails, or the rock at the sides of the crack, and in a month after

the placing of the station, it will be unfit for use.

Fourth.—Into a hole drilled in the roof, a wooden plug is driven, and into this we drive the spad. The swelling wood clamps the same and prevent its coming out as readily as it was put in. The plugs are made of well-dried wood outside, and are carried by the man that sets the stations. The first holes were made by a jumper, and the plugs were 2 in. square and 6 in. long. The modern holes are usually made by a twist drill of as small a diameter as will do the work without bending at the shank. Such drills can be used in slates or clays; but an ordinary drill and hammer must be used in harder rocks. The average modern holes are \(\frac{1}{2}\) in. to \(\frac{1}{4}\) in. in diameter, while the plugs are \(\frac{1}{4}\) in. long at the maximum. The smaller the hole, the quicker the work. All stations should be put in the roof in preference to the under side of a collar, or in any ordinary timbering. The only exception is where the roof is too poor to hold them. Such stations should be checked in extending a survey before they are used, if we wish to swear to the accuracy of our work. The engineer that believes in using collars may find himself in the quandary of the man whose company worked across their line because he started from a collar station. Since its location, the place was working and the collar was taken down and shifted end for end when replaced. Good side notes, if consulted, would have shown him the change.

Fifth.—A twist drill $\frac{1}{27}$ in. in diameter is used to make a hole in the roof; a piece of cord—or, better, a copper wire—is placed across this, and a hardwood shoe peg is driven into the hole and binds the cord tight. The plummet is tied to the lower end. A cord will soon rot, and, if in the gangway, is pulled out by the drivers for whip lashes, while the wire is more permanent; but even this will be pulled out by catching in the topping

of a car in a low place.

Lasty.—The use of spads is dispensed with, and all the stations put in rock roof where possible. A ½" twist drill makes a vertical hole 1 in. deep. Into this, when a sight is to be taken, the foresight man puts a steel clip with serrated edges. This is made by bending upon itself a thin piece of steel ¼ in. wide. When the ends are pressed together it will go into the hole, and the spring of the sides and the serrated edges hold the clip in the hole so that it is hard to pull out. The cord passes through a hole in the center of the bend and is, therefore, in the center of the hole—no matter how the clip is inserted. It is removed by pressing together the ends of the clip. This is the easiest and quickest way of working, as there is no eyehole to be freed from dirt and no knot to be tied and untied. The hanging of the plummet takes a fraction of a second, and the station will remain as long as the roof keeps up. The disadvantages are the putting of the holes inclined to the vertical by a careless man, and the many roofs that are unit for piercing with a twist drill.

Marking Stations.—We should have some regular way of witnessing our stations. In general, a vertical line on the rib calls attention to a station in the floor near the side marked. A roof station has the mark around it, as has been described, and it is some geometric figure. If three regular corps are engaged in the same field and meet in the same mines, as the company corps, the corps of the individual operator, and the private corps that is looking after the interest of one or more of the land owners, they must use different signs for stations. The most common are the circle, square, and

STATIONS. 59

triangle. If the "circle" corps puts in the station, it has a circle about it. The next corps uses it and puts a square about it and notes "Sta. 472 = to Sta. 742 of () Corps." The third corps uses it and puts a triangle about the square, and notes "Sta. 617 = to Sta. 472 of () Corps, and Sta. 742 of () Corps." If the first corps uses the station again, it notes the numbers given by the two other corps, and these three numbers will aid in identifying it if one or two of the numbers are lost.

Distinguishing Stations.—Each station must be lettered or numbered so that it can be readily recognized when the subsequent surveys are made. When set it may have been at the end of a gangway, while six months later the gangway has been driven hundreds of feet from that place, chambers have been turned off in what was solid, and the place be so utterly unlike its former state that nothing but a fixed mark belonging to that station alone will enable us to recognize it. The methods of distinguishing stations vary widely. In one place the writer found that each gangway and room had a Station 1 at its beginning, and the various stations numbered 1 were designated "Grog Run 1, 2, etc."; Pat James Gangway 1, 2, etc."; and so on through the map, that showed between fifty and one hundred stations numbered 1, so that a new engineer would have had to learn the mine thoroughly before he could extend a survey. Another way is to use A1, A2, etc., up to A100, and so through the alphabet to avoid running up too high numbers. A third was lettering the various sections of the mine A, B, C, etc., and the numbers begin with 1 in each and run up indefinitely.

All of the above have disadvantages, as powder or lamp smoke, mud, mold, or the misplaced ingenuity of small boys may so obliterate or obscure

All of the above have disadvantages, as powder or lamp smoke, mud, mold, or the misplaced ingenuity of small boys may so obliterate or obscure a mark that it will be recognized only by association with its immediate neighbors, and these may have shared the same fate. You may have only a part of the mine map with you, and because the system of marking strives to get along with as few symbols as possible, you have to go to the office, when there would have been a chance of deciphering the mark if there had been a number of figures to it. The best practice, therefore, courts large numbers, begins with Station 0 at the mouth of the slope or drift, or the foot of the shaft, and numbers consecutively in each bed. In a short time three figures are reached, while in old mines the numbers require four digits. The chances of obscuring such a mark are lessened, while the chances of our

deciphering it are increased.

Centers.—When the station is in the roof, there must be something for the transit to set over, as it is easier to do so than to set under a station, and much more accurate as instruments are now made. The set-up is made over a "center." At first, a cross scratched on the floor or on a loose piece of slate, a daub of white lead on the same with a small piece of coal placed under the point of the plummet—when that had been steadied—or finally, a nail driven into a block and afterwards pointed, were used. All of these, except where the mark was on the solid floor—if they were large enough to be stable—were in the way of the observer's feet, while, if small, they were so light as to be readily displaced. It must be noted here that it is not so much the errors that we can foresee and detect that influence the accuracy of the work in our own eyes, but the chances of error from accidents that we cannot control and that cannot be readily detected. To avoid the above chances, we make the centers as small and as heavy as we can—in other words, we make them of lead. A hole 1½ in. in diameter and ½ in. deep is bored in a thick plank, a brad is set in its center with the head down; the hole is filled with melted lead and the brad is slightly raised to surround the head with lead, and held with pincers in a vertical position till the lead has set. The brad is cut off ½ in above the lead and pointed. This "center" combines weight and small size, and is generally used.

Paint.—White lead, or Dutch white, thinned with linseed oil, is ordinarily used. It is carried in a covered tin pail holding a pint. The cover has a hole large enough to admit the brush. The pail generally has to be cleaned out after each day's work, as the brush gathers dirt every time it is used. In case the paint is to be kept for a number of days, it must be covered with water, which can be poured off before using. If the ordinary paint brush has too long bristles, it can be shortened and kept from wearing by winding with fine wire to the proper length. The top should be wiped clean and dry with a piece of cotton waste before the paint is applied, or the white will be so discolored as to be scarcely visible, or if the top is dirty it will fake off, and the numbers be lost.

KEEPING NOTES.

Taking Notes.—Complete notes should be taken and recorded neatly and systematically, so that a stranger can easily follow them. Every physical characteristic, and all surface improvements should be noted and located Every ledge of rock should be noted, its character, dip, and course of strike should be taken. In a large company there should be a separate book for transit notes and for side notes, and where many collieries are operated,

separate set of books should be used for each colliery.

However the notes are kept, we must note the following things: The numbers of the stations; the needle readings to check the vernier; the vernier reading; the dip of the sight; the distance measured, either flat or on the dip; the height of the axis of the transit from the ground; the height of the point sighted at from the ground; and all other necessary remarks to make the work plain. It is customary to have series of vertical column headed (to suit the above) Sta., Needle F. S., Needle B. S., Vernier, Pitch,

Dist., H. I. (height of instrument), H. R. (height of rod, or point to which sight was taken), and Remarks.

At the top of the page in starting a survey, there should be entered the name of the mine and of the bed where the work is to be done; the names of the regular corps employed for the work, and those that were taken from the mine to point out work or assist; the instruments used; the date of the work, and in case it be the continuation of a previous survey, the pages where such work was noted must be set down. Such books are complete records, and can be used as time books in paying the men, or as proofs of the kind of work done in case a lawsuit requires such testimony, by showing the number of men, the instruments used, and the time employed.

Transit and Side Notes. - There are about as many methods of keeping these notes as there are engineers. These methods arrange themselves into groups. and specimens of four groups will be shown, as the most common in use in

the mines:

First.—The side notes of each sight follow the transit notes of that sight, and on the same page.

Second.—They are entered in the same book on opposite pages.

Third.—The transit notes of the whole survey come first, and are followed by the side notes in the same book.

Fourth.—Each set of notes has a separate book.

The last method is the best—even if the same man takes both sets of notes, and where two men do the work at the same time, such a method is imperative. Each mine should have a separate set of books for ordinary work and special work, and such a practice gives the engineer reference notes in a portable form. Unless this is done, and if the party makes surveys in twenty different mines, the notes of two succeeding surveys in any locality are generally in separate books, and both must be carried. This applies to side notes, and four books must be carried. With a special book for each mine, no index is needed to find a certain survey, and no set of books must be overhauled. The book for that mine is taken, the date looked up, and the notes found.

The taking of side notes in an ordinary outside survey is secondary to the instrumental work; while in underground work, of ordinary character, the lines of the survey are skeletons upon which are built the side notes. The side notes are therefore of the highest value, and the forms for taking them should embrace the salient features of the underground work, so that the mapper can reproduce them faithfully even if he may never have been

inside.

Forms for Transit Notes.—Suppose we are setting up at b; with backsight at a; foresight to c; deflected angle $abc = 85^{\circ} 27'$ left; and that the distance bc is 421.76 ft. measured on a pitch of $+4^{\circ}$ 35'.

First Form:

Sta.	Needle. B. S.	Veri	nier.	Needle.	Pitch.	Dist.	Sta
Dua.	B. S.	A	В	F. S.	11011	2350.)
$-a \atop b$	S 25° 30′ W	L 85° 27′	L 85° 26′	S 60° 0′ E	+ 4° 35′	421.76	c

This is read: "Set-up at b; backsight at a; foresight to c; first reading of vernier under A; second (check) reading under B; check reading by needle computed from foresight and backsight needle, etc." Some note the readings of one vernier at A, and the opposite one at B, and take only one sight. The last column for stations is sometimes omitted, and the first widened, so that the three can be entered as fol-

lows: " a-b-c.

0238 167.62

0237

F1G. 2.

Second Form.—This differs from the first in having but one column for the venier reading, which is not noted until two readings agree, and also in omitting the last column for stations, as noted above. In some cases the line is indicated by but two stations, the one set up at, and the foresight, as in the angle given above, b-c. To note the backsight, the previous line is always taken, and under "Sta." we put "a-b." and the needle reading.

Third Form.—In this case a continuous veris carried and the readings are put in the second column, with the needle course on foresights as a check in the third. In the column for stations only the station at which the set-up is made is noted on the line with the readings for that set-up-the backsight going on the pre-

vious, and the foresight on the following, lines.

Fourth Form.—This is also a form for recording a continuous vernier, as well as the deflected

FIG. 1.

angle. The right-hand page is for noting differences of level as measured by level or transit. Certain columns are filled in at the office, to make the book complete as a reference in mapping, or in the mine. This form is advocated "for its compactness"; but there is such a thing as too much of that article, as there is no room on either page for remarks, while in all the other systems, the right-hand page is set aside for this purpose.

Fifth Form.—Where the leveling is performed by the transit, and each sight is taken with that end in view, the level notes are added to any form of transit notes chosen and they are recorded as shown in table on page 56.

These figures are used to calculate the differences in elevation, as shown by the pitch of the sight. The minus signs show that the points noted are below the stations. If the station were in the

floor, the sight would have a plus sign. uous vernier can be used with this form.

Forms for Side Notes.—In every case the notes should convey to the man that plots some idea of the form of the place surveyed. An accurate sketch cannot be made unless the whole locality can be seen at a glance—which is seldom, if ever, the caseand yet we must not go to the other extreme and write down the notes without a sketch; yet that is what is frequently done, and may be simply noted as the first form, and put aside as a faulty method with no good points.

Second Form.—In this, see Fig. 1, as in a sketch made as a person advances with no definite idea of the arrangement of the work, there is too frequently a running of the sketch off the page-on one side or the other, and a cramping of certain parts. Inserting the figures on the line of survey confuses the one that plots if the sketch is distorted or cramped. As the hands of the note man are dirty from rubbing along the tape, to find the numbers, it generally happens that the sketches are smeared and blurred so that they are hard to decipher when the notes are most clearly kept, and a method that encourages cramping, confusion, or obscurity must be rejected.

Third Form.—There is no attempt made at sketching in this form, Fig. 2, but the red line in the center of the page of the note book is taken as the line of survey, and the next parallel lines on either side are taken as the boundaries of the solid on either side. The only figures on each side of the red line are the distances from the line to the solid, while the "pluses" at which the were taken are noted at the side of the page, and the exact distance betwee the two stations is enclosed in the parallelogram. This method at the pluses 155 and 157 calls attention to a point where practice varies greatly namely, How shall we note the "corner of pillar"? and Where is the corner One method calls the corner that point where the pillar begins to diverg from the gangway line, as noted in Fig. 2, at a, where a chamber, crose cut, or counter starts from the gangway; a second method designates the corner as the first or last solid part met with in the line of survey, as at Fig. 2. The first is faulty, as there is no record of the gradual divergence of the pillar from the gangway line, and the words "corner of pillar" usually mean the end of the same. We should therefore call the pillar solid till the line at right angles to the line of survey is tangent to the ends, no matter whether that end be 10 or 100 ft. distant. Any one can plot side notes if accurately taken, and two persons accurately plotting such notes will reach the same result.

Level Notes.—These are kept as in outside work, as has been before stated with the exception that, as the rod is reversed in getting the elevation of station in the roof, the record of the reading is prefixed with a minus sign. A record of such a reversed rod, when the target is 3.78 ft. below the station.

is recorded -3.78.

The shaft is measured (if deep) by a fine steel wire running about an accurately graduated wheel (a sufficient number of turns being laid to prevent slipping) and noting the number of turns before the bottom is reached. The wire may be measured before and after the operation, to insure against stretching. An aneroid mining barometer, if in good condition, will give quite accurate results if a number of trips are made between top and bottom, to give an average. In this case the barometer must be left quiet 10 or 15 minutes, to be sure that it has expanded or contracted to the proper degree. For rough measurements, the length of the winding rope between top and bottom is taken.

By one of these methods we locate a bench mark below, that is connected with the outside work and referred to tide water. As has been stated, the rod must be reversed to get the elevation of all stations in the roof, and all such readings are noted with the minus sign, as —4.32 (read 4.32 ft. below station). We must bear in mind that roof stations are almost certain to settle, from the pressure of the superincumbent rocks. To check such settling, we must measure the distance from roof to floor accurately. Some measure from floor to rail of track. This is inaccurate, as the track may be shifted or the grade changed in making repairs, or to take out a "sag." A noted expert once swore that the roof had settled in a mine, as his measurements were from roof to track, and the latter had been raised without his

knowledge.

Whenever we begin a level survey, we must measure the distance between roof and floor and see if it agrees with the notes. If it differs, we must note the fact under the original notes, as a check for future work.

STOPE BOOKS.

By Joseph Barrell.*

In large metal mines, where the veins are more or less vertical and great volumes of ore are extracted from between the levels, it becomes important to adopt such a system for recording the shape and location of the stopes that at any future time the engineers may be able to give precise information concerning them, without entering the mine for the purpose.

Preparation of the Stope Book.—Although the timbering furnishes means for sketching and locating the stopes, some regular system must be followed or inextricable confusion will result. The book must connect the stope sketches with the transit work of the drifts and also the various floors with

one another.

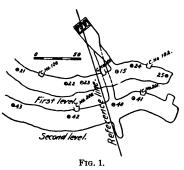
Fig. 1 is a hypothetical map of a portion of two levels. Figs. 2, 3, and 4 follow from it. Fig. 2 being one leaf from the stope book. The paper should be of the quality of that used in field books, ruled by the printer vertically and horizontally, with waterproof lines in a colored ink—preferably green. A convenient scale has been found to be 4 lines to the inch, every fourth or

^{*} See "Mines and Minerals," October, 1899, page 97,

fifth line to be heavier. Each square will represent a square set, giving an actual scale of about 20 ft. to the inch. A smaller scale does not show enough detail, and a larger one is not necessary for this class of work.

The most convenient size for the bound books is 11 in. long by 51 in. wide.

Only the right-hand leaves are numbered, so that when open a page extends entirely across the book, 20 in., showing 400 ft. of the length of the vein and wide enough for two floors on The floors immeone page. The floors immediately above each other must follow on consecutive pages; thus, on the first double page will be 400 ft. of the sill floor and first floor, on the second page the second and third floors, and on the seventh page the twelfth and thirteenth The eighth page is reserved for cross-sections of the vein, and the ninth for the long upright section, these two being shown by Figs. 3 and 4. The next 400 ft. of the same drift will be shown on page 10.



so that it joins on to page 1 on one side and to page 19 on the other, and in this way the work of one level is kept together. For convenience, the book should be indexed by placing a projecting tag with the number of the level on each page of the drift floor.

Having now a general idea of the arrangement of the work in the book, it

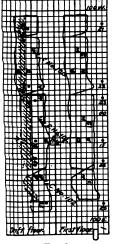


Fig. 2.

remains for us to determine, precisely, how to place it and how to show the relation to the transit surveys. First, it is necessary to have some reference line on the vein. For this purpose draw on the map, through the center of the shaft, a line perpendicular to the strike of the vein, as shown in Fig. 1. Scale off from the map the distance at which it cuts the transit course from the nearest station. Then, by adding the known distances between stations to this, we obtain the surveyed distance of any point on the drift from our reference line. Select the middle or end of a page in the stope book for the zero or reference line, such that the drift will go most conveniently in the book, and on the upper line locate the survey points at their proper distances from it, as in Fig. 2. The vertical location of any part can be told when the dimensions of the timbering are known. In this instance the drift is 7 ft. 10 in. high, and each of the following 12 floors are 7 ft. 2 in. If the levels are exactly 100 ft. apart, the thirteenth floor will consequently be 6 ft. 2 in. in height.

The Stope Book in the Mine,—Having indi-

The Stope Book in the Mine.—Having indicated in the office, by a regular system, the place for everything that will be found in the mine, the next step is to proceed to the details of sketching. The location of the stations on the top line of the drift-floor pages shows on what vertical line they should lie in the sketch; but the fact that each square must be kept as representing a square set, and that any or all of them may not be exactly to our

scale, will cause the location made in the mine to vary slightly from that made in the office. Any such discrepancy must be taken upon the edge of the page. Therefore, proceed to the station nearest the center of the page

and locate it as nearly as possible under its position at the top, remembering that the sets of timber, no matter how irregular, must be represented as squares. Now walk along the drift, watching the character of one side at the line of the floor, sketching while walking, counting the sets, and indicating the posts by dots of the pencil. Check up the number of sets on each station and continue to the end of the drift. Sketch the other side in coming back, and by counting the sets a second time, from station to station, a further check is placed upon the work. On the correctness of the sketches of the

drift floor that of the overlying stopes depends.

Having finished the drift, climb to the first floor and locate the set climbed through the same distance east or west of the reference line as on the drift below, see Fig. 2. Since the chutes and manways will ordinarily not step off sideways, but only along the dip, a chute will be represented the same distance from the side edge of a page on all those floors where it occurs. In this way each floor is located in longitude. To do the same in latitude it will be necessary to give an arbitrary number to that row of timbers on the ground floor against the hanging wall. It is well to start with 10, since then, on a wider working of the hanging wall, there will be no danger of running down into negative numbers. The rows are numbered consecutively as they step off toward the foot-wall. Thus, in Fig. 2, on the drift floor, the manway is on row 19. In such a manner each floor is completely located with reference to the drift below and ultimately with the transit survey.

reference to the drift below and ultimately with the transit survey.

The ease and rapidity of the work will depend on the character of the mine. Much is gained by practice, the work not being sketched set by set, but a pause for sketching being made every fifth or tenth set, or wherever there is a change in the character of the wall. In drifts such as are usually found, from 3,000 to 8,000 ft. of sketching is a good day's work. The sketch should be taken at some definite horizon, and that of the floor level is best. Features of constant recurrence must be represented by conventional signs.



FIG 3

Thus, in Fig. 2, c enclosed by a square indicates a chute passing through the floor; up means a ladder up; M, a manway down. A full line indicates a rock wall, a broken line, lagging; cross-hatching represents filling: a dashed-and-dotted line, the presumed limit of filled workings, etc. It is of importance to indicate irregularities in the timbers. If it is a short set, write S within the square: if a long set, L, giving the length if necessary. If there should be an angle in the timbering so that there may be a set more on one side of the drift than on the other, represent it by a wedge-shaped opening, as shown, being the appearance of the drift if it were straightened out. In sketching, it is essential to accuracy that the attention be held to a few things at a time. On reaching the top of the raise the plan views are completed, each floor having been sketched on the way up. On descend-

ing, turn to page 8 and sketch the cross-section of the manway, as shown in Fig. 3. Each set is still represented by a square, although the sets are higher than wide, but since that fact is known it can lead to no error.

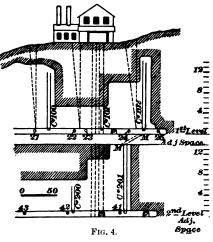
The stope book is taken through the mine and brought up to date at the first of each month, and it is necessary for the foreman or shift boss to accompany the engineer and point out each place where work has been done. To pick up the work readily, and identify the last set of the previous month, the last cap should have a notch cut in it and the same indicated in the book.

The Long Section.—The view of the vein that will be of most general use, and show at a glance the progress of the work of ore extraction, is the long section. It is a modified vertical projection of the vein, such as would be obtained if the rock on the hanging-wall side should be removed and the vein viewed from a distant standpoint at the same level. Fig. 4 shows the final section made in the office to the same scale as the map, but each part of it for the corresponding 400 ft. of a level will be placed on pages 10, 19, etc. of the stope book, and is compiled from the sketches of each floor. The long sections can be drawn from the plan views of the floors either in the

mine or the office, but it is a little better to determine the *limiting* points in the mine. The transit stations, chutes, and raises should, of course, be located upon it as common points with the map, connecting the two. The final long section is drawn by merely piecing together the several parts from the stope book and drawing them horizontally and vertically to the same scale.

Since a vein is quite an irregular surface, the question arises as to what modification of a vertical projection will give the most accurate and convenient representation of it. That devised by Mr. A. A. Abbott, of which the essential feature is the horizontal adjustment space left between the levels, is shown in Fig. 4. At our reference line, in this case the projection of the shaft upon the vein, the zero points of the levels are placed over each other. But owing to the warpings in the vein, a raise, such as No. 201, started, in this case, 40 ft. east, will not break through on the similar point of the level above. The simplest way in which to allow for these discrep-

ancies is to draw the levels more than their true distance apart by the width of an adjustment space, lay each level at its true length, and draw the raises perpendicular to them, provided, of course, that the raises only step off along the dip and not along the strike. All these features can be appreciated by studying Figs. 1, 2, 3, and 4 in connection with each other. Lines corresponding to the height are ruled on the sides of the drawing, the floor on which the work is being done is ascertained by means of a parallel ruler. Such a view approximates to a development of the vein horizontally, but vertically to a projection, since the vein is projected on a



series of vertical planes passing through the transit courses. The drifts are shown at their true lengths, but the heights are the vertical distances and

not the lengths up the dip.

The long section will be brought up to date every 3 or 6 months, and the portions of the veins extracted during the interval indicated by cross-hatching or tinting. In the illustration, the ore bodies are cross-hatched to bring them out more clearly, but to do this on the regular map would involve crasures with every extension in the workings. In the mine, a hard and sharp drafting pencil will be used, but pencil markings in a book constantly in use soon become faint and blurred. It is necessary to go through the book at intervals and ink in everything with waterproof drawing ink. Two colors can be used with advantage, red for all transit lines and survey figures, and black for the stopes and those symbols relating to them. If there are several splits to a vein, sometimes worked together and sometimes not, the work on the different splits can be readily distinguished on the long section by using red for the hanging-wall split, and blure for that of the foot-wall. If old filling is taken out, such as ore, as frequently hapens, the parts extracted can be cross-hatched in red, and thus a record of both the first and second extractions preserved.

The value of these methods over mere sketches made without system lies in their accuracy. Where the timbering is irregular, the accuracy of the

results depends largely upon the time and care taken in the work.

MINE CORPS.

The method of dividing the work in an underground survey depends on the size of the corps. We will therefore consider the work of each man, in order to get the right number for the corps. The chief of the party should be where he can do the most good, and where he can plan the work for his subordinates. The principal point of the survey is the setting of the stations so as to do the work thoroughly with the fewest set-ups, and thus diminish the chances of error in instrumental work. The chief should locate the stations and add all the necessary sign to show how the work is to be done. The transituman should not have his attention distracted from his particular work by questions as to procedure. He should work untrameled. The chief, therefore, should not run transit. Upon this basis the ideal mine corps works, and such a corps run transit. Upon this basis the ideal mine corps works, and such a corps consists of at least four, and better five, men from the office, and three from the mine. It is divided into two sections. The chief takes the men supplied by the mine-one or more of whom are acquainted with the work done since the last survey—and locates the stations; the transitman follows with the second section, to measure angles and distances. By this time the stations are set and the chief takes his men after the transit party and gets the side notes, with a check measurement of the distances between stations.

Such a corps goes to the end of the former survey and identifies the last two stations. The transitman prepares to set up at the last, while the chief and party goes as far as he can see the light from the last station, or to some intermediate point from which one or more sights are to be taken. He then stops and sends a man along each place where a sight must be taken, as long as their lights are plainly seen from top to bottom where he is standing, and over this place he marks a point for a station to be inserted, and generally inserts it himself unless he be pushed by work, and must leave it for another to do, when he places a circle about the dot, places the number at the side,



to do, when he places a circle about the dot, places the number at the side, and as many arrows as there are new stations, the longer arrow generally pointing to the sight to be last taken and where the transit is to be set up next. Leaving a backsight at the point just set up next. Leaving a backsight at the point just set, he sets, successively, stations at the points where the foresight men have stood, in the manner just described, until he has covered the new work—the mine boss or some intelligent miner going with him to give him an idea of the "lay of the ground," so that the work can be covered with the fewest number of stations. Sometimes the chief takes the side notes and measures the distances between stations as fast as they are set. In a pitching place, a circustations as fast as they are set. In a pitching place, a circular brass protractor with small plummet is hung at the center of a stretched tape, to give the angle at which the tape is held; this serves as a check to the measurements of the transit party, which are taken as the basis of the work, and the other measurements are solely as checks.

In flat work, both measurements should coincide.

In a small corps, and where time is of little importance, the foresight man puts in the stations ahead of the transit, and while he is so doing the transitman takes the side notes. Sometimes the side notes are taken by the same man, while one of the party is taking the transit to the next station and setting it up for the next sight. There are about as many variations from these two methods as there are corps.

The foresight man should be intelligent and active, as the amount of work done in a day depends on his ability to keep ahead of the transitman. Some of the latter are fast enough to keep two foresight men on the jump. His duty is to set the center for the next set-up under the station, and also place the tripod if three are used in the work, to give the sight, and, in some corps, to carry the front end of the tape and assist in taking the distance. In some corps he also carries the bag with tools for setting stations, so that he generally has a load that makes rapidity of movement difficult, and anything that will diminish the weight carried will tend to quicken the work.

The rapidity with which good work is done varies considerably, but it depends on the activity of transitman and foresightman, and a good corps should have no trouble in making twelve set-ups an hour, and taking two or three sights from each set-up. It varies also with the distances between stations. The saving of time should never be sought at the expense of accuracy in the work: it is to be gained by rapidity of moving about. in the latter are fast enough to keep two foresight men on the jump.

of accuracy in the work; it is to be gained by rapidity of moving about, in

setting transit, center, etc., and in hanging plummets to give sight. The foresight man and backsight man should be in position to give sight before the transitman is ready, so that he can turn his instrument on one or the sther and find them in position. The slowest parties were those that carried ampty powder kegs (in the days when loose powder was allowed inside) for seats, and spent the greater part of the time sitting on them. The backsight man has little to do inside, and to compensate for this, he

is the one that cleans and oils the tape, gets out new plummet strings, and sees that the tools are ready for the next work, as soon as the corps gets to

the office.

The transitman cleans the transit, unless the corps has subordinates that can be trusted with so delicate an instrument. The blackening from sulphureted hydrogen is rubbed from the silvered surfaces with whiting, and the oil or paint smears are removed with alcohol. Alcohol should be used instead of water for cleaning the instruments, and especially the lenses, which are wiped with jewelers' cotton or soft chamois skin.

SURVEYING METHODS.

Outside Surveys .- We have spoken of the points necessary to include in the survey outside, and how the base line is established. It remains to call attention to several points that must be known before the surface plant can be protected from settling, from the removal of the deposit below. The exact location of all buildings, lakes, ponds, rivers, raifroads, etc. is not only necessary for the making of a correct map; it is necessary for the determination of the amounts and location of the beds that must be left untouched by the subsequent mining. Here must be mentioned an error that generally governs the location of the retaining pillars to support the above and prevent damages to themselves or to the mine. The settling of the ground would make all bodies of water leak into the mine, and also destroy to a greater or less degree all surface plant, as well as throw out of plumb all shafts or other openings for hoisting, if it did not close them entirely. The usual custom is to extend vertical planes through the boundary lines of such objects, and leave untouched all parts of the superincum-bent beds embraced by those planes. This is accurate only when the strata are horizontal or vertical, as beds settle normally to the planes of the strata and not in a vertical line in case the open spaces are stowed. If the spaces are left open, they are first filled by falls, and then the settling goes on according to the above rule. No cut is necessary to show the method of settling, and the place where the bed is to be left untouched may be found as follows: Draw a vertical section through the point to be supported, and also the underlying bed on the line of the dip of the bed—the section being accurately drawn to any scale. Draw through the extremities of the object to be supported, lines to the bed, which will make right angles with it. The space included will give the dimension of the pillar measured along the dip of the bed, and the dimensions of the object taken at right angles to the first plane will give the other dimension of the pillar.

Inside Surveys.—As the beds of anthracite lie at all angles with the horizontal plane, the methods of surveying them vary accordingly, and can be divided into flat and pitching work. Flat work is where the beds have so slight a dip that the cars can be drawn to the face of the room, and where there is nothing to prevent a sight to that face from the gangway. The variations in the methods of work in this case depend on the accuracy with which the work must be performed, as, in some cases, the workings are approaching the boundary line of the property, and the sides of the rooms must be located accurately. In general, the rooms are driven at right angles to the gangway, unless the dip is too great to haul a car to the face on that line, when they are inclined to the gangway at an acute angle. The width of the rooms in flat work is generally uniform where the roof is good, but where the roof is poor the entrance is narrowed for a short distance (to better support the gangway) and then widened to the full width, or the whole is driven to the limit narrow, and the side is robbed when the top is drawn, and the whole room caves in. This last must be surveyed before the robbing

begins.

The most accurate method of survey is to run a line along the gangway and put a station at the entrance of each room, whence a sight is taken to the face. This may be varied by putting the stations at alternate rooms and measuring through the cross-cuts to get the thickness of the pillars of the intermediate rooms, or placing stations at every third room and measuring the thickness of pillars and width of rooms that intervene; or, finally, by running out the gangway with as few sights as possible and paying no attention to the positions of the rooms in setting stations, thence up to the last room to the face, and back through the cross-cuts nearest the face to the former work, where at it is made. When opportunity offers, sights are made from the face of the rooms to the stations in the gangway for immediate ties. In case a gangway and airway have been driven considerably ahead of the rooms, it is always necessary to run lines out each and tie at the last cross-This must be done in every case where the gangway is approaching the boundary line, or old workings that have been abandoned and are full In addition to this check the miners must keep bore holes 20 ft. ahead in the line of the gangway, and every 20 ft. must drive others from the corners of the heading at an angle of 30° with the line of the gangway. In this way there will be no danger of running into "a house of water," as the Cornish miners call it, if the survey be inaccurate.

Pitching Work.—When the bed pitches so that a car cannot be run to the face, and when there is a good deal of firedamp in the mine, it is generally difficult to see from the gangway to the face, where the roof is good and the room straight, as a buggy track or chute, or both—when the pitch is slight fill up the room, and, where the pitch is great, the gangway pillars generally run across the face, or there is a "battery" shutting off the bottom of the room, so that the face can be reached only by several sights. Where the roof is poor, the obstructions are increased, as the rooms are driven narrower. or, if wide, have center props and stowing in the center. If the coal is full of slate, or if the partings are thick, a large part of the room is taken up with piles of "gob," and with a very poor roof the body of the room that has been worked out is filled with the fallen roof, and the coal is sent out through the

triangular manways, where it is almost impossible to take a sight.

Work of this kind is surveyed by lines out gangway and back through the faces of the rooms, which are generally clear, even if the bodies of the rooms are filled with the fallen top. Where chance favors, sights are taken to the gangway; but this very seldom happens, as the two lines are as effectually separated as if in different mines. From the stations in the faces, lines are run down the rooms as far as possible to get their direction, and to locate the cross-cuts. The very worst case of all is where two beds are separated by a thin parting of rock and the gangway is driven in the lower one alone, the rooms in the upper one being worked by rock chutes into the rooms below, or into the chutes from those rooms. This class of work is hard to ventilate, and to survey where the rooms above are ventilated by the air system of the lower beds; but is readily mapped where there is an air system for each bed.

Closing Surveys.-To diminish the chance of error and to furnish a ready Closing Surveys.—To diminish the chance of error and to furnish a ready check, the survey must be closed upon itself or some part of a former survey with every twelve new stations. With good work the error in arc in a close should not exceed 1', and the error in position should be less than 6 in Errors must not be "balanced"; they must be detected and rectified by running the line again, if they are not readily seen from the methods to be given. If an incorrect survey be balanced, each subsequent one must be altered to fit this incorrect work, though it may be correct in itself, and we never know where our work really stands. It is well, therefore, to check the work in order soon as we make a close and before the party leaves the the work in arc as soon as we make a close and before the party leaves the place, as it is easy to rerun the work then.

CONNECTING OUTSIDE AND INSIDE WORK THROUGH SHAFTS AND SLOPES.

As the dip of the bed increases, it is less easy to make a connection, and the chances of accuracy diminish. In a survey, R. Cos. Vert. Angle is what locates the station with regard to former work. The greatest angular accuracy for a given value of R is where Vert. Angle = 0° and R = Cos. Vert.As the pitch or vertical angle of sight increases, the above cosine diminishes until, at a vertical sight, R. Cos. Vert. Ang. = 0°

In the case of an adit level, or a slope of less than 45°, there is no difficulty beyond the want of absolute rigidity in setting up the transit, and the danger of moving it in going about it. The difficulty increases more rapidly than does the pitch, and as R. Cos Vert. Ang. diminishes, though R be fixed, the chances of error increase. When the slope reaches 60° there is an impracticability in running a line down a slope, as the line of collimation of the telescope strikes the graduated limb of the instrument. We can use a prismatic expeice and see up the slope; but cannot look down. As we have assumed that it is unnecessary to use an additional telescope, we shall have to run the line by intermediates. Set up at the bottom of the slope where the longest sight up the same can be secured and backsight on a station of the underground work; or set a backsight for the occasion (both stations will afterward be connected with the work below). With the prismatic eyepiece, sight up the slope on a line that will give the longest sight and, at the same time, afford a good intermediate place to set up the transit, as, on a pitch of 60° or more, it is absolutely necessary that the legs of the transit should be set solidly (in holes in the floor, or between the sills of the track) so that they will not be moved by subsequent walking about it. By this method, all the sights will be taken from one side alone, and the tripod legs can be shortened to make the sight possible without building a standing place—if the man be short-legged.

Call this station A: at the foot of the slope locate B, where the transit can be readily set up, and as far up the slope as we can see (this distance must be at least 100 ft.), and in a continuation of AB, locate C. Set up at B and take foresight to C; locate D under the same conditions that governed the placing of B, and, in a continuation of the line BD, place E. Set up at D with foresight at E, and locate F and G as before. The survey is carried by the intermediates B, D, E set to the ton by a series of foresights to C. E, G at

foresight at E, and locate F and G as before. The survey is carried by the intermediates B, D, F, etc., to the top, by a series of foresights to C, E, G, etc.

Shafts.—The term shaft in American coal-mining practice is applied only to vertical openings, though in metal mining, both in this country and abroad, it is also applied to highly inclined slopes. For such shafts, most of the methods given in the textbooks are worthless, as they are for transit work and R. Cos. Vert. Ang. in rare cases may be as great as 20 ft., while R varies from 100 to 1,500 ft. Again, to sight down a shaft necessitates the erection of a temporary (and therefore more or less unsteady) support for the tripod of the transit, and the chances of variation in its position as we stand on different sides of it are so great that we cannot feel sure that a movement has not taken place that will vitiate the work.

In sighting up a shaft of greater depth than 100 ft., there is annoyance—if not denote—from displaces. In a

In sighting up a shaft of greater depth than 100 ft., there is annoyance—if not danger—from dripping water or the fall of more solid substances. In a wet shaft the object glass is instantly covered with water, and a sight is impossible. We must also have a platform to stand upon, and we cannot feel sure that this will be perfectly rigid. From all these considerations the methods with a transit are never used by engineers in the anthracite regions,

and the connections are made as follows:

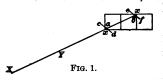
When the bottom of the shaft can be reached by an adit or slope in a roundabout route of such length as to render errors in measurement of distance of great importance, the angles are carried by a transit with as long sights as possible, and no distances are measured, from a point on the surface in the shaft to a point vertically below it in the mine. Sometimes the guide of the cage is taken when it has been recently set, as the guides are plumbed into position; but the better way is to suspend an iron plummet by a copper wire: sink the former in a barrel of water so as to lessen the tendency to swing on account of the pull upon the "bob" and wires from the air-currents, or falling drops in a wet shaft. The top of the barrel is covered with two pieces of plank with a semicircular groove of 3 in. radius cut out of the middle for the passage of the wire, to catch the substances whose fall upon the water would cause waves. The heavier the plummet and the lighter the wire, the less the tendency to swing. This wire can be sighted at by parties above and below at the same time, and the swing can be bisected to get the position of the wire. A number of sights that agree can be taken as accurate.

When the shaft is the only way to get below from above, it must be plumbed with two or more wires suspended as just described. With two wires, they are so hung that an instrument can be set up below in a line passing through them produced, and at a sufficient distance from them to insure an accurate sight; with more wires, the station below can be located

at any point whence all the wires can be seen.

Case 1.—Two wires are used, which are located as far apart as possible. Two pieces of scantling cd and ef, Fig. 1, are spiked across the opposite corner of two compartments of a shaft to allow the cages to pass up and down

without interference. The station X is (roughly) located in a line through the corners x, x and is connected with the outside survey. From this station locate in the line Xxx two spads for holding the wires of the plumb-bobs. These are driven up to the head in the scantlings in such a way that the line of sight passes through the center of the holes in their heads. Measure the distances Xa and ab. This completes the work of the survey above ground.



The light copper wire is rolled upon a reel, and one end is fastened to a light plumb-bob to keep it free from coils or kinks in descending. It can thus be readily lowered without accident. When at the bottom, the upper end is fastened in the spad and the heavy "bob" applied to the bottom and placed in the empty barrel. The cages

with an observer on each, to see that the wires hang free from top to bottom. By this time the wire will have stretched so that it will be straight. and if there be any slack, it is taken up, the barrel is filled with water, and

the top boards put in place. As a last check, measure the distance between the wires below and see if it agrees with the distance above.

Lining in below a point Y on the line ab, make a hole in the roof two inches in diameter, and drive in a broad plug. Setting up the transit under Y, we sight at the wires a and b alternately. A number of methods for illuminating the wires have been used, and are given in textbooks. The writer has always found those depending on a sight of the wire across the flame of a lamp the hardest to obtain, and concludes from experience that the method of illuminating the wires for mine surveying is the best for this also. A large white target is placed behind both wires and illuminated by a large lamp white target is placed behind both wires and illuminated by a large lamp with a reflector behind it. The wire stands out black against it and can be followed across the target. As there is considerable distance between the wires, and as the transit is comparatively near them, there will be small chance of getting a sight of one, when the telescope is focused upon the other, and so the focus has to be set between them. This gives a hazy sight at each; but both are shown against the white background in strong relief. After the transit head is shifted so that the line of sight coincides approximately with both, focus upon them alternately and see if the line bisects the swing of each. If so, the work is done; if not, the shifting of the transit head must follow till the end is attained. It frequently requires two or more hours of steady observation to complete the work and, when it seems as if head must follow the the end is attained. It requently requires two or more hours of steady observation to complete the work and, when it seems as if the proper point were secured, one of the wires will show by its swaying that it has been deflected from the vertical by a peculiar slant of wind, and the result obtained must be checked again. When you are through, there is no absolute certainty that the point you have marked is in the accurate extension of the line ab at the surface. Having decided on the proper place. you drive a spad into the plug overhead; hang a plumb-bob to it, and see if it be over the axis of the transit, as shown by the screw on the telescope. If not, drive the spad so that the point of the bob does so hang, and the station Y is said to be in the line ab. Measure Ya and the angles to any station of the underground survey; the line ab is connected with the surveys at daylight and below, and the plumb-bobs may be removed.

Criticism of the Above Method.—1. As has been stated, there is no absolute certainty that the point Y is in the line ab prolonged, and this want of

certainty should not exist in so important a measurement.

The work must be performed by daylight, and the length of time necessary to complete it makes it impossible to work the shaft for at least half a day, and may cause annoyance to the operators, or, if you are working for a lessee, lead them to refuse to let you have the use of the shaft at the

time most suitable for your purpose
3. It may be hard to obtain a long sight below on any line running
through the larger axis of the shaft. Any shorter line would give too short a base line and would increase the chances of error. To avoid these, another

method is sometimes used.

CASE 2.—Fig. 2 shows the top set of timbers in a shaft of two hoisting compartments, down which it is desired to carry a known course or meridian on the surface to the entry below. First find out which side of the shaft is best adapted for setting up the transit, as the point to be marked in the mines will be vertically under the point on the surface; consequently,

HORTH

the side with the widest opening leading from the foot of the shaft should be selected.

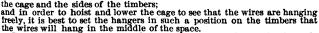
Having carried the meridian to a convenient point near the top of the haft, and having found that the south side of the shaft is the most accessible, determine, with an ordinary string, the location of the point A, from which the hangers for the plumb-lines will be exactly located by means of the transit. Now mark with chalk on

the timbers where the strings cross. These marks, though not accurate, serve as guides in setting the hangers. Make a permanent station at the point A and carry the meridian to it.

The hangers can be made of strap iron, 1 in. thick by 2 in. wide, and at least 16 in. long. In one end of the iron, have a jaw with a fine cut at the apex, or a drill hole just large enough to contain the wire to be used for plumbing. There should be two or

three countersunk holes in the hanger, through which to fasten it to the timbers by means of heavy wire nails. top view of the hanger is shown in

Fig. 2. In most shafts there is a space from 2 to 4 in. wide between the ends of



Fasten the hangers permanently over the chalk marks previously made on the north side of the shaft, with the jaws pointing toward A, and on the south side of the shaft the outer end of the hanger may be fastened

temporarily

Now set the transit over the station at A, take the backsight, foresight on the wire hole of the hanger C and set the wire hole of the hanger B on the same line. Record this course and foresight on the wire hole of the hanger E, fixing as before the wire hole of the hanger D in the same line. Record this course, and then the meridian to be carried into the workings below is established. Measure carefully and record the distances A to B, A to C, and B to C, the distances A to D, A to E, and D to E, and finally the distances B to D and C to E. The necessity of taking all these measurements is for the purpose of establishing a point at the bottom of the shaft vertically below A, and checking the work in the office.

The transit party can now descend to the bottom of the shaft, taking with them four buckets of oil, the weights or plumb-bobs to be attached to the wire, and all the surveying instruments, leaving a responsible party on the surface to handle the wires. Having arrived at the bottom of the shaft, have the cage hoisted 3 ft. above the landing, throw several planks across the timbers on which to set the buckets of oil, signal to the man on top to lower a wire and to fasten it securely, passing it through the wire hole of the hanger; now attach the plumb-bob and adjust the wire to such length that, when sustaining the full weight of the plumb-bob, the latter will not touch the bottom of the bucket. Insert the weight in the oil using care not to leave the full weight on the wire with a jerk, but let the weight down slowly, so that the wire receives the full strain gradually. three remaining wires in a similar way.

After the wires have been hanging a few minutes with the weights attached, the latter may move from one side to the other of the buckets. Watch this carefully and keep moving the buckets until all the weights hang perfectly free, then leave everything alone until the wires become steady. The cages can now be hoisted and lowered for the purpose of examining the wires to see that they hang free and plumb, care being taken that the cages are not brought so close to the landings as to disturb the hangers at the top, or the buckets at the bottom.

To find a point vertically below A, stretch a string along the wires B, C being careful not to touch them; stretch another along the wires D, E; then, with a plumb-line, determine a point on the bottom vertically below the intersection of the strings. Measure the distances A B, A D, B D, and C E and compare them with the corresponding distances at the top of the shaft. If these distances compare favorably, the wires are, in all probability, steady, and the work of determining the desired course with the transit may now be begun.

Set the transit up over the point of intersection just found; backsight on the wires B, C; foresight on the wires D, E, and compare the included angle and the distances with the corresponding angle and distances at the surface. If these do not correspond, move the transit in the direction

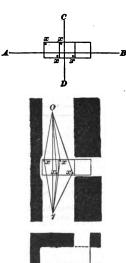


Fig. 3.

necessary to increase or decrease the angle or distances, as the case may be. Repeat this operation until the exact point verti-

cally below A is determined.

A simple device that is of great advantage is to have three links from an ordinary trace chain placed in the wires on the side toward the transit, and a few feet above the buckets. This not only enables the wires to turn freely, but also enables the transitman to sight through one of the links to the wire beyond, whereby he can place the transit in exact line with the wires more easily than if the links were not there.

CASE 3.—Two, three, or four wires are employed. They are secured and hung as employed. They are secured and the angles of the segmentments x, x, x, x, Fig. 3. These are connected with four stations A, B, C, D, the lines A B and CD being at right angles to one another for convenience in the subsequent calculation, and are connected with the outside survey. From A and B, taking AB as a base line, the points x, x, x, x are The same is repeated from C and located. D, taking CD as a base line. We thus have four locations of each wire. These are tabulated, and any variations in a reading must be followed by a repetition of the The mean of the readings gives the same. location. (Subsequently, the subject of cal-culating work will be taken up.) It can be briefly stated here that the bearings of each wire to each of the others, as referred to the base line of the survey, are then calculated and the distance between the wires accurately measured. This finishes the work at

daylight.

There may be two general types of arrangements of the bottom of the shaft, and both arrangements have been sketched and lettered similarly. The first is a case when the shaft is arranged across the dip of the bed, and the second is parallel to the same. In both cases O and 7 are taken as far apart as possible, and all the wires x, x, x, x, z located from each station with

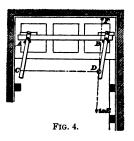
reference to the other. The distances between the wires above and below are also accurately measured as a check. There will be four locations of θ and 7 from the four wires, and the mean of these is taken as the correct one. In every case of angle measurement mentioned, a series of readings of each angle is taken upon different parts of the graduated limb, to avoid instrumental errors, and the mean of these taken as the true reading. From the locations of θ and 7, the course between them, as referred to the mean base line is calculated, and θ 7 is the base line for the underground work. The angle readings above and below can be made at the same time with different instruments, and, in taking the readings below, it is not necessary to wait for absolute quiet in the wires, as that is seldom found. A small swing can be bisected by the cross-hair, and the readings are duplicated until a

onstant result is secured. By this method a greater accuracy and speed is beained, and the angles below can be accurately measured, no matter how he shaft may be arranged.

The T-Square Method. - This ingenious method of taking the line underround is especially valuable in shafts with several small compartments or n cramped places where one cannot line in

with the wires.

The wires are placed in separate comartments and as far apart as possible. The apparatus is made by the carpenter, and consists of a straightedge and T squares. The former is merely a planed pine board about 8 in. \times \ddagger in. and a foot longer than the distance between the wires. It rests approximately horizontally on slats tacked across the shaft for supports. It is brought to about an ‡ or in from each wire and then nailed to the slats sufficiently to prevent slipping. One man should be at each wire. The T squares are most serviceable if made with a movable head clamped by a thumbscrew, and of planed pine, about 2½ in. × ½ in. Except in cramped quarters, the T squares will be set at right angles, and should be placed together in clamping to insure



that each is set at precisely the same angle.

Fig. 4 shows a cramped position such as sometimes arises and in which the movable head gives more latitude in working. After clamping, the T squares are slid along the straightedge until close to the wire, but not touching it, and are there clamped by a "G" clamp, both men working at one The ends of the T squares, C and D, must be supported on T square. blocks so that the vaquares lie approximately in the same horizontal plane. Everything up to the next step need be only approximately and quickly placed, but now the greatest care must be exercised in measuring out equal placed, but now the greatest care must be exercised in measuring out equal distances, AC and BD, from the wires. If the wire vibrates, determine the middle of its swing by a pencil or pin. Hold a footmark (not the end of the tape) opposite the wire on the T square, measure out an even number of feet, and mark the point with a sharp pencil, and insert a pin. This done for both wires gives us the parallelogram ABDC, in which the only essential is that CD should be exactly parallel to AB, the line of the wires. Now set the transit over the most convenient of the two points, as B. To get the azimuth of BC and consequently the line of the wires sight on a known azimuth of DC, and, consequently, the line of the wires, sight on a known point E for a backsight, and measure the angle E D U. Establish another point as F, on the line of the backsight, in order that its course may be preserved after the instrument and T square are removed.

By this means the closing angle at E may be read after the wires are removed from the shaft. Underground, the method is the same, except that DC is the known course, and is used as the backsight. To give the coordinates of the instrument at D with the greatest precision,

the angle ADC and the distance AD should be measured.



FIG. 5.

Surveying Slopes or Inclined Shafts.—Where a single sight reaches from top to bottom of the shaft, the problem is simple enough. A station can be established on the inside of the foot-wall plate at the collar and others in similar positions at each level. The instrument set up over any station can command the whole shaft and the level opposite.

Where the shaft is sunk on several dips, the survey

is a much more difficult matter. Fig. 5 illustrates cases of common occurrence. The shaft may be divided into sections like $A\,D\,E\,B$, which are convex downwards, and others such as $E\,B\,C$, which are concave downwards. As a rule a set-up can be avoided at the convex knuckles if desired, and need only be made at those that are concave.

Bent Plumb-Line Method.—A may be invisible from B, but the survey may be

^{*} See "Mines and Minerals," January, 1899, page 242.

carried from one point to the other by the ingenious method of the bent

plumb-line.

The most complicated example which can arise is shown in Fig. 5. Establish a station at A, the foot-wall side of the collar, the center point being a small nail head projecting horizontally. Attach a long plumb-line to this and carry the other end to B. Here it will probably be necessary to use a small screw-eye, with its head turned into the vertical plane of the shaft, for the center point. Pass the plumb-line through this and draw it fairly tight. Now attach a plumb-bob at an intermediate point and regulate the tautness so that the line is clear at all points.

The curves in the shaft may be such that two plumb-bobs may have to be

hung, as at D and E, and even a third may become necessary.

The plumb-line, perhaps 100 ft. long, is apt to be disturbed by the aircurrents, and it is often better to mark a point on a convenient timber near D, and another near E, so close to the string that there is no doubt of the points lying in exactly the same vertical plane as the plumb-line. If these points be once established, the string and weights can be taken out of the shaft, leaving us four points in the same vertical plane, and whose horizontal

projections lie in the same course.

Now set up at A and measure the azimuth angle from the backsight to D, Now set up at A and measure the azimuth angle from the cackinght to B, thereby giving the bearing from A to B. If D should be invisible from B, depress the telescope after sighting on D and locate the point N in the same vertical plane, and so situated that it is visible from both A and B. Measure the vertical angle and distance to N. Now set up at B, use the course B of a backsight, and foresight to C. Measure the vertical angle and distance B N. It is seen that B N might have been used as a backsight, and E only converted to B N. serves as an additional check. N is really an intermediate station, but since it lies in the course AB, a set-up there is unnecessary. In simple cases, it is a very convenient method of carrying a survey from the surface to the first level, and a longer horizontal projection of the sight AD can be secured than if a set-up were made in the shaft at D; but in complicated cases, such as the one shown, it may often be quicker to make the extra set-up than to use the plumb-line. In all sights for determining azimuth, keep the vertical angles as low as possible, and the horizontal projection of the course long.

Method by a Single Wire in the Shaft.—Stretch a rather fine wire, free from kinks, down the shaft, as shown in Fig. 6, being careful that it touches nowhere in the shaft. Take two plumb-bobs provided with fine round strings. Suspend one from A and the other from B so that they nearly touch



strings. Suspend one from A and the other from B so that they nearly touch the same side of the wire M N. In order to have the plumb-lines as far apart as possible, the line at B must be quite long and a can of water should be provided to keep the bob from swinging. The plumb-line is fastened to a nail B nearly in the proper position. Have a bar of wood with a block fastened to it placed to one side of B and a little below it. The block must have a hole so that a small screw bolt can easily screw through it. A spool is run on the bolt having a small groove turned in it and being sandpapered and greased so that the string will slip easily as the bolt is turned. Now, place the transit in line with the two plumb-bobs as in an ordinary case of shaft plumbing. Repeat this operation below. The plumb-bobs in both cases hang in the same vertical plane and thus the true bearings are found underground. Even the and thus the true bearings are found underground. plumb-lines could be dispensed with, but the method would not then be so accurate. The instrument would be set nearly in the vertical plane passing through the wire, leveled and sighted at M. Dip the telescope until the lowest point on the wire is visible, note the amount by which the cross-hair and

Fig. 6.

wire fail to coincide and shift the instrument accordingly. if this method were tried, the two points sighted at would not be nearly so far apart horizontally as the plumb-lines, and any error in leveling would also vitiate the result. This method of the single wire, however, provides no way of obtaining the coordinates.

NOTES ON MAPPING.

There are no general rules governing the minutize of map making, so that it may be well to note some of the variations in practice. In some offices the area excavated is shown by a light wash of India ink in addition

to the ink line bounding the solid area. This makes a striking map, and the workings stand out prominently. If the survey were never to be extended and the map were simply made to show a particular state of the workings, there would be no objection to the practice; but as such extenconkings, there would be no objection to the practice; but as such calculations have to be made, and old pillars removed or cut up, it requires conderable skill to tint the extensions, and especially the surfaces when the surface when the surface, so as to produce an effect uniform with the old inted surface, especially as that tint has been deepened by frequent han the surface, especially as that tint has been deepened by frequent han the surface, especially as that tint has been deepened by frequent han the surface when the surface we will the tint on the man, but some tint

dling. For these reasons many offices omit the tint on the map, but some tint the back of the tracing used by the corps, or sent to the mine inspector.

It is an open question whether the ends of the chambers (breasts, rooms) and gangways (entries, levels) should be closed with ink. It is well to be able to show on your map where the faces of the workings were at any given time. Some place the date of each survey at the ends of the gangways at each posting, and of every fourth or fifth chamber, and thus note the rapidity with which the mine is worked. Others use various colors to denote the successive postings of the survey, and place across the ends of gangways and

chambers the color appropriate to the survey that located them.

Where there are a number of beds worked from the same shaft, slope, or adit, the workings are frequently vertically above one another, and their location on the same map causes confusion unless care be taken. One of the methods used to distinguish between each bed is to line in the areas worked with a color appropriate to that bed. In this way, three or four beds have been plotted on the same map. A better way is to make a map for each bed and to combine the various beds on the tracings for the officers and the mine Each bed on this is lined with its color, and tinted with a wash inspector. of the same color on the back of the tracing on the parts excavated.

The lines of survey are lightly drawn between stations with red ink, and the stations denoted by minute circles of the same color as that used for that particular seam. The survey lines should never cut the circumference of the circle, as such a procedure might cause doubt as to the exact location of the station in case measurements were made on the map. Stations are numbered as in the mine, and beneath each is placed the elevation above or below tide of the roof of the mine. If the stations are numerous and the elevations frequently taken, such a map would furnish the means of ascertaining the quently taken, such a map would furnish the means of ascertaining the shape of the bed by running contours through points of equal elevation. This plan was used by a number of engineers and was adopted by the Second Geological Survey of Pennsylvania in making their mine sheets. The adoption of the scale of 100 ft. to the inch, under the ventilation law, also furnished that survey with a means of tracing and connecting adjoining properties and their workings, as had been frequently done by large companies having adjacent collieries, and the maps of the anthractic regions of the Second Geological Survey of Pennsylvania have been thus compiled from tracings of office maps, with little or no justice work by the corporative survey. tracings of office maps, with little or no inside work by the corps of the survey.

The ground areas of all buildings are tinted a uniform red.

All railroad tracks are represented by red lines.

All bridges, etc., and, in fact, any improvements built by man, are to be colored red.

In the mine, the stations are represented by a small circle (o) with the number in black beside it.

The lines of survey are drawn between the circumferences of the circles marking the station o--o, so as to leave the centers uncolored. elevations above tide are marked.

All small bodies of water are tinted with Prussian blue; all large bodies

with indigo—as Prussian blue is too vivid for large areas of tint.

It is the custom to allot a color to each bed, and make each bed on the general tracing in its color. In this way all the beds may be mapped on the same tracing, and can be distinguished though the workings may all under-Various colors are sometimes used to denote the extent lie the same area.

of the workings at the given postings.

The paper on which the map is made should be of the best quality, as frequent changes in the workings, and the removal of portions of old pillars, necessitate many erasures. Ordinary paper will not work well after erasure and subsequent handling, and the best practice is to use cloth-backed egg-

It remains to note that the temperature and humidity of the office, and of the place where the maps are stored, should vary as little as possible. scale is small, any variation in the paper by contraction or expansion will

affect the scale on which the map was originally laid out, and will affect it unequally, as the paper is not homogeneous. This can be seen by making measurements on old maps to check work done in former times. In almost measurements on old maps to check work done in former times. In almost every case the 500' squares are slightly in error. This must be guarded against in case measurements are taken from the map. It is best to calculate the distances wanted from the coordinates of the ends of the lines, and insure absolute accuracy.

A good map is the sign of a good draftsman. The title should be subordinate to the map. It is common to see the fifty-cent map of a small area smothered under a gorgeous ten-dollar title. The lettering should be neat and appropriate, and a style should be adopted that can be readily thrown

off—as time is quite an item in the money made by mapping.



FIG. 7.

A neat title, the judicious use of tints over the area excavated, and good lettering of minor objects will add dollars to the value of a map. A small outlay of taste and care will make a beautiful tracing out of a ragged one. and double its value.

Locating Errors.—Errors in arc or distance easily located by the method of coordinates. transitman, at the completion of a closed survey, should rum the angles and see if it be 360°. before leaving the mine, a check will be established on the transit work. In case of a variation from 360°, the notes are examined to see if the needle readings show a similar variation with the vernier.

In case the notes are incomplete, or, if a continuous vernier has been carried, we table the work before leaving the mine and locate the error as follows: Fig. 7 represents a close of

Sta.	Course.	Dist.	N	s	E	w		Su	ms.	
SIE.	Course.	Dist.	, A	٦	E	"	N	S	E	w
a b c d (d') a (a") b	N E S 30 E S 60 W N 30 W	100 100 100 100	100	86.58 50	100 50	86.58	100 100 13.42	36.58	100 150 63.42	

four stations and an angular error at c. Starting from a we table as follows:

There is an error in close of 30°, as the course a"b differs from the course a b by 30° . Reversing the order of tabling, and correcting each course by 30°, we have:

Sta.	Course.	Dist.	N	s	Е	w		Su	ms.	1000
ou.	Course.	Dist.	1,				N	S	E	W
$egin{array}{c} a \\ d \\ c \\ b & (b') \\ a & (a') \\ d \end{array}$	E N N 60 W S 30 W S 70 E	100 100 100 100	100 50	86.58	100	86.58 50	100 150 63.42		100 100 13.42	1

Upon comparing the sums of the northings and southings and eastings and westings in both, we find that c is the only station for which they agree. Here the error occurred. The location of c from either direction was correct, and what followed incorrect. From this we can deduce the rule:

To Find an Error in Arc.—Table the close from any station in both directions back to the initial station. The station which has a similar sum of eastings and westings and northings and southings in both tablings is the one at which the error was made.

With two or more errors nothing can be done.

Errors in Distance.—These may be found in a close by tabling. Suppose we have a square a b c d so placed that the magnetic meridian passes through b d. Let the distance c d be incorrect.

Sta.	Course.	Dist.	N	8	Е	w		Su	ms.	
Sua.	Course.	. Dist.	N		E	"	N	s	E	w
a b c	N 45 E S 45 E S 45 W	100 100 150	70.71	70.71 106.06	70.71 70.71	106.06	70.71	106.06	70.71 141.42 35.36	
d a	N 45 W	100	70.71			70.71		35.35		35.35

The first location of a is southings 0, westings 0; the second location is southings 35.35, westings 35.35. The westings are sines and the southings cosines, as stated before. As sin + cos = tang of course referred to the base line, we divide 35.35 by 35.35 and obtain 1 as the natural tangent for 45°, and, as the error was in southings and westings, the course on which the error was made is 8 45° W. The amount of the error is found by dividing the error in eastings or westings as tabled by the sine of the course just found, or the error in northings or southings by the cosine of the same. Both results will agree, $35.35 \div 70.71 = .50$. Reducing the measured distance by this amount, we find the tabulation shows an accurate close. From this we deduce the rule:

To Find an Error in Measurement.—Divide the difference between the eastings or westings of the two locations by the difference between the northings or southings of the same. The quotient will be the tangent of the course on which the error was made. The extent of the error is found by dividing the

error in eastings or westings (as tabled) by the sine of the above course, or the error in northings or southings by the cosine of the same.

Locating Special Work.—This last principle may be used for finding the proper course and distance to drive a tunnel between two stations connected by a survey. In outside tunneling, the survey is generally carried over the surface in a straight line. In underground work this is impossible, so that is a much more difficult task to ascertain the distance and direction to drive, from the number of measurements to be made in connection with the two stations, but if the work is accurately done it is much more a feat than in outside work. To include all the elements that enter into such a calculation, we will suppose that an underground slope is to be run between two beds of The distance between the two ends must be accurately obtained, as coal. well as the relation of the two stations found. Having tabled the work, we get the difference between the sums of sines and cosines, as just described, for the two points; the quotient from dividing the first by the second gives us the course, and from the last rule the horizontal distance is found. levels give us the difference in elevation, and from these data we get the slope per hundred, and the distance measured on that slope. All of the work is done in the mine and while the transit is setting up at one of the end stations, so that before leaving the mine, we can give the course, pitch, and distance of the tunnel and set the first station for lining in the center. more important the work, the greater need of accuracy. In one case a 1,000 chain was constructed to measure the distance between two shafts that were to be connected by work driven from both ends, and much of the outside work was done on the ice of the Susquehanna River, and a transit reading to 5" was used. The work closed vertically and laterally within an inch.

Calculation of Areas.—In connection with the mapping of the part newly worked, the engineer of the company sometimes calculates the area excavated since the last posting, and estimates the royalties accruing to the

various parties whose lands are leased.

This method, at best, is liable to grave errors, and requires a number of accurate cross-sections of the bed to determine its composition, as well as numerous determinations of the specific gravity to determine its weight. The old method of estimating workable coal in a property allowed 1,000 tom per acre per foot of thickness of the bed. To obtain this amount, the roof must be good, the pillars of medium size, and the bed near the surface; or the surface must be so valueless that the pillars can be "drawm" or "robbed." As beds increase in depth, if the surface be valuable, the ratio of pillars to stall must increase or the greater pressure will cause the mine to cave in. It has been found that, when the surface is to be kept up and the workings are to be carefully driven, but 850 tons per acre per foot of thickness can be used in calculation, under the present system of mining. Efforts are constantly being made to increase this amount, with a possible chance of success.

To estimate the amount of coal excavated from any property, the best method is to institute an account of all cars of coal taken out from the workings under that property. As soon as the measurements on the mine tracing show that a gangway or room has crossed the property line, the office is notified, and all cars coming from those places are credited to that property. This is the only absolutely accurate method of computation. The total number of cars of coal run through the breaker is known, with the total weight of prepared coal. The ratio of the cars coming from a given property to the total number of cars is taken as the ratio between the total prepared coal and the coal sold from that property.

RAILROAD CURVES.

These are generally circular, and divided into simple, compound, and reverse curves. A simple curve has but one radius, a compound one is con-

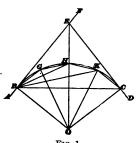


FIG. 1.

as but one radius, a compound one is continuous and has two or more radii, and a reverse one is also continuous but composed of arcs described in opposite directions

Curves are designated by the number of degrees in the central angle, which is subtended by an arc whose chord is 100 ft. long. Thus, if the angle B O G, Fig. 1, is 10° and B G is 100 ft. long, B G H C is a 10° curve.

The angle *FEC*, formed by the prolongation of two adjacent straight portions of a railroad, or tangents, as they are technically called, is termed an intersec-

tion angle.

The deflection angle of a curve is the angle formed at any point of the curve between a tangent and a chord of 100 ft., and is therefore one-half the size of the degree of the curve. If the chord B G is

degree of the curve. If the chord BG is 100 ft., the angle EBG is the deflection angle of the curve BGHC, and is one-half the angle BOG.

When the deflection angle D is given, the radius of the curve, R, is found by the formula

$$R = \frac{50}{\sin D}.$$

The curve used to connect two tangents is determined mainly by the form of the country. When this is decided, the point of beginning, called the P. C. (point of curve), and the point where the curve ends, called the P. T. (point of tangent), must be located. Both these points are the same distance from the point of intersection of the tangents, called the P. I. (point of intersection). This distance is called the tangent distance of a curve, and is found by the formula

$$T = R \tan \frac{1}{4} I$$

in which

T =tangent distance;

R = radius of curve;I = intersection angle.

Having set the tangent points B and C. Fig. 1, in order to locate points on the curve, set up the transit at B, the P. C. Set the vernier at zero, and sight to E, the P. I. Suppose B to be a full station on the tangent, and that it has

wen decided to set stakes at each 100 ft. Let the central angle B O G, meas-red by the 100-ft. chord B G, be 10° ; then, the deflection angle E B G, having vertex B in the circumference, and being subtended by the chord B G, ill equal B G G, or 5° . Turn an angle of 5° from B, which in this case will to the right, measure 100 ft. from B, and drive a stake at G. ditional angle of 5°, making 10° from zero, and at another 100 ft. measured om G, and drive a stake at H. Continue this process until 20°, or one-half he intersection angle, has been turned off. This last deflection will bring he forechainman to the point of tangency C, or the P. T.

When the P. C. comes between two stations it is called a substation, and he chord between it and the next station on the curve is called a subchord. and the P. C. been a substation, say 32 ft. beyond a regular station, the effection angle for the measuring distance of 100 - 32 = 68 ft. would be bund in this manner: The deflection for 100 ft. is $5^{\circ} = 300'$; hence, for 1 ft.

300 = 3', and for 68 ft. it is $3 \times 68 = 204' = 3^{\circ} 24'$. This is turned off 100

and a stake set in line 68 ft. from the transit. Other stations are then located

as above, by turning off an additional 5° each time.

Rules for Measuring the Radius of a Curve.—Stretch a string, say 20 ft. long, or longer if the curve is not a sharp one, across the curve corresponding to the line from A to C_i in Fig. 2. Then measure from B the center of the Fig. 2. Then measure from B the center of the line AC, and at right angles with it, to the rail at D. Multiply the distance A to B, or one-half the length of the string, in inches, by itself; measure the distance D to B in inches, and multiply it by itself. Add these two products, and divide the sum by twice the distance from B to D, measured exactly in inches and fractional parts of inches. This will give the radius of the curve in inches.

It was be more convenient to use a straightedge instead of a string. Care



It may be more convenient to use a straightedge instead of a string. must be taken to have the ends of the string or straightedge touch the same part of the rail as is taken in measuring the distance from the center. If the string touches the bottom of the rail flange at each end, and the center measurement is made to the rail head, the result will not be correct.

In practice, it will be found best to make trials on different parts of the

curve, to allow for irregularities.

EXAMPLE.—Let AC be a 20-ft. string; half the distance, or AB, is then 10 ft., or 120 in. Suppose BD is found on measurement to be 3 in. Then 120 multiplied by 120 is 14,400, and 3 multiplied by 3 is 9: 14,400 added to 9 is 14,409, which, divided by twice 3, or 6, equals 2,4011 in., or 200 ft. 11 in., which is the radius of the curve.

The formula is thus stated.

$$\frac{A B^2 + B D^2}{2 B D} = R$$

Or, applied to the above example.

$$\frac{120^2+9}{2\times3}=2{,}401\frac{1}{6} \text{ in.}=200 \text{ ft. } 1\frac{1}{6} \text{ in.}$$

To Find the Redius of a Circular Railroad Curve, the Straight Portions of a Road Being Given.—If QI and PD, Fig. 3, are the straight portions that are to be connected, the radius of the curve ID may be found as follows:

Produce QI and PD until they meet and form the angle T. Bisect the angle QTP by the line TC. From the point on either line from which the curve is to begin, in this instance making the point I the point of curve, erect the line IC perpendicular to QT, and the point where this joins the line TC, or C, is the center of the curve, and the line IC is the radius. To find the end of the curve, or point of tangent, as D, draw a line from C, perpendicular The line CD will also be a radius of the circle of which ID is the arc, and the point D will be the point of tangent.

To Find the Radii of Compound Curves to Join Two Straight Portions of Road. This kind of curve is adopted where the railroad is required to pass through

given points, as C, D, E, F, Fig. 3(b), or to avoid obstructions.

Compound railroad curves are composed of straight lines and circular arcs, and have common normals, OH, OP, PI, QJ, KR, and therefore common tangents where the arcs are joined. The normals are perpendicular to the straight portions of the road also; OH is perpendicular to AB, EF is perpendicular to QJ and KR.

To find the radii OB, CQ, Fig. 3 (c), to connect two straight lines of rail road, AB, DE, the road has to pass from the point B, through the **point** C and to touch the straight road EF at any point D. Join B and C, make the angle BCO = OBC, which is supposed to be given, equal $90^{\circ} - TBC$. Draw BO perpendicular to AB, then OB = CO.

and is the radius of the arc B C.

With OB as radius, describe the arc BC; draw CF perpendicular to CQ, and produce DE to meet it in F; make DF = CF, and draw DQ perpendicular to EF, to meet CQ in Q. Then CQ = QD, and the radii OB and Q D are determined.

Practical Method of Laying Out Sharp Curves in a Mine.—Curves in a mine are usually so sharp that they are designated as curves of so many feet radius,

instead of as curves of so many degrees.

instead of as curves of so many degrees. Suppose that it is required to connect the two headings A and B, Fig. 4 (a), which are perpendicular to each other, with a curve of 60 ft. radius. Prepare the device shown in Fig. 4 (b), by taking three small wires or inelastic strings f g, g h, and g k, each 10 ft. long, and connecting one end of each to a small ring, and the other end of two to the ends of a piece of wood $1\frac{1}{2}$ ft. long. Form a neat loop at the end f of the string gf. To use this deviced long. Form a neat loop at the end f of the string gf. To use this device, lay off on the center line of the heading B, c d and d e equal to 60 ft. and 10 ft., respectively. Place the loop f of the device described over a small wire peg driven



in at e, and the ring g over a similar peg at d. Take hold of the stick h k, pull the strings g h and g k taut, and place the center mark on h k on the center line of the heading B. Drive a small peg in at m, located by the point k, which since the curve. Move the device forward, place the loop f over the peg at d, the ring g over the peg at m, and take hold of the stick h k and pull until the strings g h and g k are

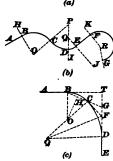
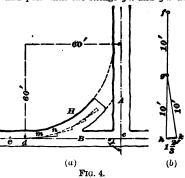


FIG. 3.



taut, and the strings fg and gh are in a straight line. The point k will fall on the curve at n, which mark by driving in a peg. To locate other points, proceed exactly as in the last step. The distance cd in any case is found by the formula cd=R tan $\frac{1}{4}I$, in which R is the radius of the curve, and I the intersection angle of the center lines of the headings.

HINTS TO BEGINNERS.

Abuse of Instruments.-Surveying instruments of value and precision are not made of cast iron, as one would think from the way they are frequently handled. Underground work is transacted in places dark, dirty, and confined, so that extra care must be observed to prevent accidental knocks that mage the instrument even if they do not destroy its accuracy.

As it frequently happens that long distances must be traversed underground in going between the shaft or slope and the workings to be surveyed, the transit and level should be carried so as to obviate all accidents. They should never be attached to the tripod and carried on the shoulder, and, if the route to be passed over is up or down a slope or working place, the person carrying the instrument should be the last to descend and the first to ascend, so that loose stones or dirt that may be dislodged will not affect or endanger the instrument or trip the carrier.

Be sure that the tripod head is tightly screwed on to the tripod. The writer remembers a case where the transitman and himself, when new to the work, spent over an hour in endeavoring to obtain two readings of an angle that would agree. The variations—from 8' to 20—were caused by the slight movement of an old instrument with too much "lost motion," and a

loose tripod head.

A great many engineers prefer kerosene to fish oil for their lamps. Kerosene never drops upon your book to make an unsightly smear, and perhaps sene never drops upon your book to make an unsightly smear, and perhaps obliterate part of your notes. A kerosene lamp is hotter and, with the glazed mine hat, is more apt to produce headaches. The writer, during the latter part of his underground work, wore a straw hat, had a piece of thin sheet brass riveted to its front with a hole in the top for the lamp hook. To the lamp was brazed a narrow cross-strip of the same metal, and the strip ends, bent back upon themselves, were slid down the sides of the plate on the hat and kept the lamp from swaying. With such an arrangement it is not necessary to remove the lamp to read the vernier, and when the lamp is used for other purposes, the hat can be removed with the lamp fastened to the programment keeps the heads free from lamp worker or ill and a This arrangement keeps the hands free from lamp smoke or oil, and a cleaner note book is the result.

When there is an antipathy to a lamp upon the head, and when, with a long, wooden handle, one or both hands are free in going about the work, a larger lamp is used of "torch" pattern, employed by wheel testers or engineers in railroad practice. Kerosene can be burned in this. The handle can be tucked under the left arm while taking side notes. Such a lamp is convenient in finding old stations in a high place, when there is no firedamp.

For plumbing wet shafts, kerosene resists the extinguishing power of water better than fish oil, and is less readily blown out by a strong ventilating current. It makes more smoke, and, in tight headings, or mines with poor ventilation, with a large party, fouls the air much more readily than fish of. Sometimes a mixture of the two is burnt in very drafty places, where it is hard to maintain a light. Kerosene is burned in the plummet lamp unless it is used with the "safety" attachment. Sweet oil, or any oil burning without smoke, must then be used. Smoke closs the openings in the gauze, restricts the entry and escape of gases, and, especially if the gauze be damp with oil, may ignite and communicate the flame from within to the outside

body of gas.

White lead or Dutch white (white lead and sulphate of baryta in equal parts) is best for painting stations. Zinc white has been tried with less success. The mixture should not contain too much linseed oil—especially

THEORY OF STADIA MEASUREMENTS.

BY ARTHUR WINSLOW.*

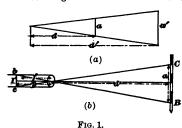
Late Assistant Geologist, Second Geological Survey of Pennsylvania, State Geologist of Missouri.

The fundamental principle on which stadia measurements are based is the geometrical one that the lengths of parallel lines subtending an angle are proportional to their distances from its apex. Thus if, in Fig. 1(a), a represents the length of a line subtending an angle at a distance d from its apex, and a'the length of a line, parallel to, and twice the length of a subtending the same angle at a distance d' from its apex, then d' will equal 2d.

^{*}Mr. Winslow's calculations and tables have been proved practically correct by the several corps of the Second Geological Survey of Pennsylvania. The corps in the authracite regions, under directions of Mr. Frank A. Hill, geologist in charge, took over 30,000 stadia sights, and better results were obtained when tie surveys were made than in previous work in which distances were chained.

This is, in a general way, the underlying principle of stadia work; the nature of the instruments used, however, introduces several modifications, and these will be best understood by a consideration of the conditions under which such measurements are generally made.

There are placed in the telescopes of most instruments fitted for stadia work, either two horizontal wires (usually adjustable), or a glass with two etched horizontal lines at the position of the cross-wires and equidistant from the center wire. A self-reading stadia rod is further provided, graduated according to the units of measurements used. In a horizontal sight



with such a telescope and rod, the positions of the stadia wires are projected upon the rod, and intercept a distance which, in

Fig. 1 (b), is represented by a.

In point of fact, there is formed, at the position of the formed, at the position of the stadia wires, a small conjugate image of the rod that the wires intersect at points b and c, which are, respectively, the foci of the points B and C on the rod. If, for the sake of simplicity, the object glass be considered a simple biconvex lens then by a principle of

Fig. 1. lens, then, by a principle of optics, the rays from any point of an object converge to a focus at such a position that a straight line, called a secondary axis, connecting the point with its image, passes through the center of the lens. This point of intersection of the secondary axes is called the optical center. Hence, it follows that lines such as $c \in A$ and $b \in B$. in Fig. 1(b), drawn from the stadia wires through the center of the object glass, will intersect the rod at points corresponding to those that the wires cut on the image of the rod. From this follows the proportion:

$$\frac{d}{p} = \frac{a}{I}.$$

$$\therefore d = \frac{p}{I} a, \qquad (1).$$

where

d = distance of rod from center of objective;

p =distance of stadia wires from center of objective:

a = distance intercepted on rod by stadia wires;

I =distance of stadia wires apart.

If p remained the same for all lengths of sight, then $\frac{p}{r}$ could be made a desirable constant and d would be directly proportional to a. Unfortunately, however, for the simplicity of such measurements, p (the focal length) varies with the length of the sight, increasing as the distance diminishes and vice versa. Thus, the proportionality between d and a is variable. The object, then, is to determine exactly what function a is of d and to express the relation in some convenient formula.

The following is the general formula for biconvex lenses:

$$\frac{1}{p} + \frac{1}{p'} = \frac{1}{f}; \tag{2}$$

 $\frac{1}{p} + \frac{1}{p'} = \frac{1}{f};$ (2) f is the principal focal length of the lens, and p and p' are the focal distances of image and object, and are, approximately, the same as p and d, respectively. in equation (1):

Therefore,
$$\frac{1}{p} + \frac{1}{d} = \frac{1}{f}, \text{ approximately,}$$
and
$$\frac{d}{p} = \frac{d}{f} - 1.$$
From (1),
$$\frac{d}{p} = \frac{a}{I}.$$

$$\therefore \frac{a}{I} = \frac{d}{f} - 1.$$
Whence,
$$d = \frac{f}{I}a + f. \tag{3}$$

In this formula, it will be noticed that as f and I remain constant for this of all lengths, the factor by which a is to be multiplied is a constant, **d that d is** thus equal to a constant times the length of a, plus f. This forala would seem, then, to express the relation desired, and it is generally asidered as the fundamental one for stadia measurements. 1 1 **±ed**, however, the equation is only approximately true, and e conjunction of this formula with (2) being, therefore, not rigidly admissie, equation (3) does not express the exact relation.* The equation expressthe true relation, though differing from (3) in value, agrees with it in rm, and also in that the expression corresponding to - is a constant, and hat the amount to be added remains, practically, f. The constant corremay be called kt, and thus the distance of the rod from the bjective of the telescope is seen to be equal to a constant times the reading n the rod, plus the principal focal length of the objective. To obtain the exact distance to the center of the instrument, it is further necessary to add he distance of the objective from that center to f; which sum may be called c. The final expression for the distance, with a horizontal sight, is then d = k a + c.

The necessity of adding c is somewhat of an encumbrance. In the stadia work of the U.S. Government surveys, an approximate method is adopted in which the total distance is read directly from the rod. For this method the rod is arbitrarily graduated, so that, at the distance of an average sight, the same number of units of the graduation are intercepted, between the stadia wires on the rod, as units of length are contained in the distance. For any other distance, however, this proportionality does not remain the same; for, according to the preceding demonstration, the reading on the rod is proportional to its distance, not

from the center of the instrument, but from a point at a distance "c" in front of that center, so that, when the rod is moved from the position where the reading expresses the exact distance, to a point say half that distance from the instrument center, the reading expresses a dis-tance less than half; and, at a point double that distance from instrument center, the distance expressed by the reading is more than twice the distance. The error for all distances less than the average is minus, and for greater dis-tances, plus. The method is, however, a close approximation, and excellent results are obtained by its use.

Another method of get-

Another method of getting rid of the necessity of adding the constant was devised by Mr. Porro, a Fig. 2.

Piedmontese, who constructed an instrument in which there was such a combination of lenses in the objective that the readings on the rod, for all lengths of sight, were exactly proportional to the distances. The instrument

[•] This is demonstrated later on.
† Is dependent on I, and can therefore be made a convenient value in any instrument fitted with adjustable stadia wires. It is generally made equal to 100, so that a reading on the rod of 1'

win aquatable stants wires. It is generally made equal to 100, so that a results on the rod of the corresponds to a distance of 100° + f.

† A notice of this instrument will be found in an article by Mr. Benjamin Smith Lyman, estitled "Telescopic Measurements in Surveying," in "Journal Franklin Institute," May and June, 1888, and a fuller description is contained in "Annales des Mines," Vol. XVI, fourth series.

as

was, however, bulky and difficult to construct, and never came into extensive use.

For stadia measurements with inclined sights, there are two modes of procedure. One is to hold the rod at right angles to the line of sight; the other, to hold it vertical. With the first method, it will be seen, by reference to Fig. 2(a), that the distance read is not to the foot of the rod E, but to a point f, vertically under the point F, cut by the center wire. A correction has, therefore, to be made for this. An objection to this method is the difficulty of holding the rod at the same time in a vertical plane and inclined at a definite angle. Further, as the rod changes its inclination with each new rowition of the transit the vertical engles of bedegight and constitution of the transit the vertical engles of bedegight and constitution of the transit the vertical engles of bedegight and constitution of the transit the vertical engles of bedegight and constitution of the transit the vertical engles of bedegight and constitution of the transit the vertical engles of bedegight and constitution of the transit the vertical engles of bedegight and constitution of the transit the vertical engles of bedegight and constitution with each new tentors are the constitution of the transit the vertical engles of the properties of the constitution of the transit the vertical engles of the properties of the constitution with each new tentors are the constitution of the transit the vertical engles of the properties of the constitution of the transit the vertical engles of the constitution with the constitution of the transit the vertical engles of the constitution with the constitution of the transit the vertical engles of the constitution with each new tentors are the constitution of the transit the vertical engles of the constitution with each new tentors are the constitution of the transit the vertical engles of the constitution with each new tentors are the constitution of the transit the vertical engles of the constitution with each new tentors are the constitution with the constitution with each new tentors are the constitution with each new tentors are the constitution with e position of the transit, the vertical angles of backsight and foresight are not measured from the same point.

The method usually adopted is the second one, where the rod is always held vertical. Here, owing to the oblique view of the rod, it is evident that the space intercepted by the wires on the rod varies, not only with the distance, but also with the angle of inclination of the sight. Hence, in order to obtain the true distance from station to station, and also its vertical and horizontal components, a correction must be made for this oblique view of

the rod. In Fig. 2(b),

$$AB = a = \text{reading on rod};$$

 $MF = d = \text{inclined distance} = c + GF = c + k$. CH ;
 $MP = D = \text{horizontal distance} = d \cos n$;
 $FP = Q = \text{vertical distance} = D \tan n$;
 $n = \text{vertical angle};$
 $AGB = 2 m$.

It is first required to express d in terms of a, n, and m. From the proportionality existing between the sides of a triangle and the

sines of the opposite angles,

or,
$$\frac{AF}{GF} = \frac{\sin m}{\sin [90^{\circ} + (n-m)]};$$
or,
$$AF = GF\sin m \frac{1}{\cos (n-m)};$$
and
$$\frac{BF}{GF} = \frac{\sin m}{\sin [90^{\circ} - (n+m)]};$$
or,
$$BF = GF\sin m \frac{1}{\cos (n+m)};$$
or
$$AF + BF = GF\sin m \left[\frac{1}{\cos (n-m)} + \frac{1}{\cos (n+m)}\right];$$

$$AF + BF = a, \text{ and } GF = \frac{CH}{2} \frac{1}{\tan m} = \frac{CH\cos m}{2\sin m}.$$

By substituting and reducing to a common denominator.

$$a = \frac{CH \cos m [\cos (n+m) + \cos (n-m)]}{\cos (n+m) \cos (n-m)}.$$

Reducing this according to trigonometrical formulas.

$$CH = a \frac{\cos^2 n \cos^2 m - \sin^2 n \sin^2 m}{\cos n \cos^2 m},$$

$$d = MF = c + k. CH.$$

 $\therefore d = c + ka \frac{\cos^2 n \cos^2 m - \sin^2 n \sin^2 m}{\cos n \cos^2 m}$

The horizontal distance, $D = d \cos n$.

 $\therefore D = c \cos n + k a \cos^2 n - k a \sin^2 n \tan^2 m.$

The third member of this equation may safely be neglected, as it is very small even for long distances and large angles of elevation (for $1.500'\ n = 45^{\circ}$ and k = 100, it is but 0.07'). Therefore, the final formula for distances with a stadia rod held vertically, and with wires equidistant from the center wire, is the following:

The vertical distance Q is easily obtained from the relation: $Q = D \tan n$. $\therefore \quad Q = c \sin n + ak \cos n \sin n$:

$$Q = c \sin n + a k \frac{\sin 2n}{2}. \tag{6}$$

With the aid of formulas (5) and (6), the horizontal and vertical distances can be immediately calculated when the reading from a vertical rod and the angle of elevation of any sight are given. From these formulas, the madia reduction tables following have been calculated. The values of a k cos n

and $ak \frac{\sin 2n}{2}$ were separately calculated for each 2 minutes up to 30°

of elevation; but, as the value of $c \sin n$ and $c \cos n$ has quite an inappreciable variation for 1° , it was thought sufficient to determine these values only for each degree. As c varies with different instruments, these last two expressions were calculated for three different values of c, thus furnishing a ratio from which values of $c \sin n$ and $c \cos n$ can be easily determined

for an instrument having any constant (c).

Similar tables have been computed by J. A. Ockerson and Jared Teeple, of the United States Lake Survey. Their use is, however, limited, from the fact that the meter is the unit of horizontal measurement, while the elevations are in feet. The bulk of the tables furnishes differences of level for stadiar readings up to 400 meters, but only up to 10° of elevation. Supplementary tables give the elevations up to 30° for a distance of 1 meter. For obtaining horizontal distances, reference has to be made to another table, which is somewhat an objectionable feature, and a multiplication and a subtraction has to be made in order to obtain the result. Last, but not least, these tables are apparently only accurate when used with an instrument whose constant is 43 meter.

The many advantages of stadia measurements in surveying need not be dwelt on here, both because attention has been repeatedly called to them, and because they are self-evident to every engineer. Neither will it be within the compass of this article to describe the various forms of rods and

instruments, or the conventionalities of stadia work.

It is seen that, in the deduced formula, the factor by which the reading on the rod is multiplied is a constant for each instrument. The question

now arises, Does this remain the case with a compound objective?

Inview of the difficulty of demonstrating this mathematically, it was decided to make a practical test of this point with a carefully adjusted instrument. The readings were taken from two targets set so that the sight should be horizontal, thus preventing any personal error or prejudice from affecting the reading. A distance of 500 ft. was first measured off on a level stretch of ground, and each 50-ft. point accurately located. From one end of this line, three successive series of stadia readings were then taken from the first 50-ft. and each succeeding 100-ft. mark. The following table contains the results:

Di-t		Spaces Intercep	oted on the Rod.	
Distances. Feet.	1st Series. Feet.	2d Series. Feet.	3d Series. Feet.	Mean. Feet.
50	.485	.4860	.4855	.4855
100	.985	.9870	.9830	.9850
200	1.985	1.9860	1.9840	1.9850
300°	2.989	2.9875	2.9870	2.9878
400	3.983	3.9800	3.9890	3.9840
500	4.985	4.9850	4.9900	4.9867

Multiplying the mean of these readings by 100, and subtracting the result from the corresponding distance, we obtain the following table:

^{*}The above demonstration is substantially that given by Mr. George J. Specht in an article on Topographical Surveying in "Van Nostrand's Engineering Magazine," February, 1880, though enlarged and corrected.

Distances. Feet.	Mean of Stadia Readings Times 100. Feet.	Differences. Feet.	Variations From Mean. Feet.
50	48.55	1.45	+.02
100	98.50	1.50	+.07
200	198.50	1.50	+.07
300	298.78	1.22	+.07 21
400	398.40	1.60	+.17
500	498.67	1.33	+.17 10

Sum of differences = 8.60; mean of difference = 1.43.

The variations between the numbers of the column of differences are slight, the maximum from a mean value of 1.43 ft. being only .21 ft. A study of the tables will show that these variations have no apparent relation to the length of the sight, and as, in the maximum case, the variation corresponds to a reading on the rod of only .0021 ft. (an amount much within the limits of accuracy of any ordinary sight), we are perfectly justified in concluding that these variations are accidental, and that the "difference" is a constant value.

We thus see that with a telescope having a compound, plano-convex objective, the horizontal distance is equal to a constant times the reading on the rod, plus a constant, and may, as in other cases, be expressed by the

equation d = ak + c.

A few precautions, necessary for accurate work, should, however, be emphasized. First, as regards the special adjustments: Care should be taken that in setting the stadia wires* allowance be made for the instrument constant, and that the wires are so set that the reading, at any distance, is less than the true distance by the amount of this constant.

For accurate stadia work, it is better to take both distances and elevations only at alternate stations, and then to take them from both backsight and foresight in such a manner that the vertical angle is always read from the same position on each rod, which should be the average height of the

telescope at the different stations.

Cases will, of course, occur where this method will be impracticable, and then the mode of procedure must be left to the judgment of the surveyor. If it be desired to have the absolute elevation of the ground under the instrument, the height of telescope at each station will have to be measured by the rod, and the difference between this measurement and the average height used in sighting to the rod either added or subtracted, as the case may be. This difference will ordinarily be so small that in a great deal of stadia work no reduction will be necessary. In sighting to the rod for the angle of depression or elevation, the center horizontal wire must always be used. By this means an exactly continuous line is measured. For theoretical exactness it is necessary that the stadia wires should be equidistant from the horizontal center wire, for, if this is not the case, the distance read is for an angle of elevation differing from the true one by an amount proportional to the displacement of the wires.

With reasonable care a high degree of accuracy can be attained in stadia measurements. The common errors of stadia reading are unlike the common errors of chaining, the gross ones (such as making a difference of a whole hundred feet) being, in general, the only important ones, and these are readily checked by double readings. To facilitate the subtraction of the reading of one cross-hair from that of another, one should be put upon an

tAs the difference is evidently proportional to the length of sight, with a 1,000' sight it would

amount to 22.5', etc.

^{*}This applies to an instrument with movable stadis wires, and not to one with etched lines or glass. In the latter case, the graduation of the rod is the adjustable portion. It has been claimed as an advantage for etched lines on glass, that they are not affected by variations of temperature, while the distance between stadia wires is. A series of tests made with one of Heller & Brightly's transits, to determine this point, showed no appreciable alteration in the space between the wires, as measured on a rod 500 ft. distant, with a range of temperature between that produced in the instrument by the sun of a hot summer's day and that produced by enveloping the telescope in a bag of ice.

ven footmark, and in the check, reading the other one. This is assuming be measurements to be made by the ordinary method, and not by the mate one of the United States Engineers.

HORIZONTAL DISTANCES AND DIFFERENCES OF LEVEL FOR STADIA MEASUREMENTS.

The formulas used in the computation of the following tables were those given by Mr. George J. Specht in an article on Topographical Surveying, ublished in "Van Nostrand's Engineering Magazine" for February, 1880. These formulas furnish expressions for horizontal distances and differences of level for stadia measurements, with the conditions that the stadia rod the held vertical, and the stadia wires be equidistant from the center wire. They are as follows:

 $D = c \cos n + ak \cos^2 n;$

 $Q = D \tan n = c \sin n + \frac{a k \sin 2n}{2};$

D =horizontal distance; Q =difference of level:

c = distance from center of instrument to center of object glass, plus focal

length of object glass;
= focal length of object glass divided by distance of stadia wires apart;

a = reading on stadia rod;

n = vertical angle;

k = reading on rod multiplied by k, which is a constant for each instrument (generally 100).

In the tables, the vertical columns consist of two series of numbers for each degree, which series represent, respectively, the different values of $ak \cos^2 n$ and $\frac{ak \sin 2n}{n}$ for every 2 minutes, when ak = 100. To obtain the

horizontal distance or the difference of level in any case, the corresponding value of $c \cos n$ or $c \sin n$ must further be added; and the mean of each of these expressions, for each degree, with three of the most common values of c, is given under each column.

As an example, let it be required to find the horizontal distance and the difference of level when $n = +6^{\circ}$ 18', ak = 570, and the instrument constant c = .75. In the column headed 6°, opposite 18' in the series for "Hor. Dist.," we find 98.80 as the expression for ak $\cos^2 n$ when ak = 100;

therefore, when ak = 570,

a k $\cos^2 n = 98.80 \times 5.70 = 563.16$.

To this must be added $c \cos n$, which, in this case, is found in the subjoined column to be .75.

In a similar manner, the required difference of level is $+10.91 \times 5.70 \times .08 = +62.27$.

One multiplication and one addition must be made in each case.

It is to be noticed that, with the smaller angles, $\cos n$ in the expressions $c \cos n$ and $c \sin n$ may be entirely neglected without appreciable error.

For values of c, which differ from those given, an approximate correction, proportional to the amount of difference, may very easily be made in these two expressions.

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	Diff. Elev.	32.14	32.18	32.23	32.27	39 39	38	3.	30.45	30.	8	8	8	39.67	32	8	8	8	35.80	35	32.98	33.02	33.07	33 11	33.15	88 83 83	33.74	83.38 88	88 88	33.37	33.41	33.46	18	35.	4
ਫ਼ਿ	Hor. Dist.	88	88.26	33	88.19	35	2	8	3	8	5	3	8	£	£	12	1	27	9	87.63	30		87.51	£	£	82.39	87.85	87.31	1.1.2	₹.	?: •≥	87.16	9	₹.	1.17
_	Diff. Elev.	30.78	8	30.87	30.92	30.97	3	90	2	31.15	31.19	31.74	3,00	8	9	31 +5	3.47	31.5	31.56	31.60	31.65	31.69	31.74	31.78	3. 3.	3.87	31.92	31.96	35.01	32.05	32.09	32.14	3	 	[략
<u>&</u>	Hor. Dist.	89.40	89.36	86.33	89.59	80	8	2	90	2	6	3	8	3	3	3	3	3	30	£	₹ 2	£.67	₹ ¥	3	98 F	33 E	Ģ ₹	£	₹ ₹	90 90 90 90 90 90 90 90 90 90 90 90 90 9	₹ %	88.39 88.39	Γ.	ਰ. 	1.13
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28	Hor. Dist.	90.45	90.42	90.38	90.35	8	8	8	8	8	90.14	6	00	3	9	5	3	5	92.	2	62.68	9/.6	?! &	3 .	£	5 E	£	.T.	£6.51	£	7 .68	89.40	۲.	.95	1.19
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2	Hor. Dist.	6	6	6	6	6	5	6	ō	6	6	6	6	6	5	8	8	8	8	8	8	90.79	90.76	90.73	69.06	90.00	39. 65	90.59	96 96	90.55	8. 3. 3.	90.45	2.	.e.	7
•	Diff. Flev.	8	8	8	8	26	8	8	ξ	8	8	8	2	2	2	2	2	7	2	2	23	2	2	5	į,	ķ	Ę,	2	2	2	2		2.	85	 ₩
160	Hor. Dist.	92.40	92.37	8.	92.31	92.58	8	3	3	9	3	3	8	3	90	61.07	8	91.90	91.87	æ	13.16	91.77	91.74	91.71	9.68 89.	9	91.61	91.58	91.55	91.53	91.48	91.45	57.	€.	1.33
0	Diff. Elev.	25.00	25.05	25.10	25.15	25.20	25.95	8	5.33	3.5	5	200	25.55	25.60	3	25.70	25.75	25.80	25.85	35.90	35.95	39.93	26.05	93. 23.	26.15	26.23 28.23	8	S. 33	8.33	26.40	26.45	56.50	ક્ષ	.27	E.
150	Hor. Dist.	8	8	S	8	8	8	8	ŝ	8	8	S	3	3	3	3	ક	3	S	ક	S;	ક	કાં	8	ક								55	8.	1.30
140	Diff. Elev.	23.47	23.52	23.58	83	89	8	2	8	8	8	8	7	8	7	24.19	24.24	24.29	24.34	21.39	74.44	54.49	24.73	57. 99. 17.	3.63	27.70		2.80 8.77	24.85	21.90	25.95		19	સ	E.
14	Hor. Dist.							8	8	8	3	8	3	8	9	93.76	3	2	93.67	3	33	93.59	93.56	8. 13.			53.45	33 33 33 33	93.39	93.36	98.33	93.30	ξ.	.97	1.21
	Diff. Elev.	12	2	8	8	ટ	દ	ż	į	32	R	Ŗ	ક	દ	દ	દ	3	3	ટ	Ş	ફા		য়		Ŗ	প্ত	क्ष	প্ল	প্ত		-		, .		8
13%	Hor. Dist.	26.26	94.91	68	98.	2	8	2	92.10	33	5	6	3	3	3	35	3	2	3.5	44	4	37.75	8.39	8. J.	ਲ. ਲ			98. F.		91.30	71.F	94.15	55	.97	1.21
₀ 21	Diff. Elev.									20.76		20.87			21.03		91.13	21 18	21.24	21 29	21.34	21.39	21.45	21.50	21.55	25.69	21.66	21.71	21.76	21.81	21.87	21.92	91.	કો	<u>اخ</u>
12	Hor. Dist.	8	8	8	8	8	ð	_	8	Š	S	S	ð	9	6	5	S	6	6	6	95.22	8	6	ŝ	ŝ	3	-	ŝ	3	ੜੱ	ಕ	ಫ	.73	86.	1.22
0.	Diff. Elev.	18.73	18.78	18.81	18.89	8	19.00	19.05	10	19.16	19.21	19.27	19.39	10.38	19 43	19.48	19.54	19.59	19.64	19.70	19.75	19.80	19.86	19.91	19.96	20.02	20.02	20.13	20.18	8	20.58	20.34	.15	8:	18
110	Hor. Dist.	96.36	96.34	96.32	96.29	86 27	9	8	8	18.	96	95	9	8	50.96	96	8	8	95.98	95.95	95.93	95.91	95.89	96 96 96	35.8	95.82 28.82	95.79	95.77	95.75	95.72	95.70	95.68	_	١.	1.25
	X.	5	0	4	9	00	2	3	17	14	2	8	8	17.	38	8	8	33	3	98	8	4	42	4	46	48	23	52	ば	26	% %	3	c_{1} c_{2} c_{3}	0 = 1.00	1.25

230 	Diff. Hor. Diff. Elev. Dist. Elev.	34.73 84.73 35.97	25.03	26.5	90 84.57 36	94 84.52 36.	98 84.48 36.	02 84.44 36.	07 84.40 36.	11 84.35 36.	15 84.31 36.	19 84.27 36	25.23 25.23 36.23 36.23	27 84.18 36	36 24 10 36	40.84.06.36	44 84.01 36	48 83.97 36	52 83.93	888	8.8	88 83.76 36	72 83.72 36	76 83.67 36	88.68	85 83.59 37	89 83.54 37	93 83.50 37	97 83.46 37.	1	- 1	1 1 1 20
240	Hor. Diff. Dist. Elev.	7 83.46 37.16	20.41	33.33	83 28	83.24 37.	83.20 37	83.15 37.	83.11 37.	83.07 37.	83.02	85.98	82.93	82.89	85.8	82.76 37	82.72 37	82.67 37.	82.63		82.49 38	82.45 38.	82.41	82.36	85.35 38.	82.27 38.	87.73	82.18	82.14 38.	88	0 .91	-
250	Hor. Diff. Dist. Elev.	82.14 38.30	နှင့် ကို	8	8	ģ	ģ	ģ	œ	ģ	ထွ က	× i	œ e	S C	o o	8	8	ģ	8		8		8	ස	జ	ස	e e		89	- 1		5,
560	Hor. Diff. Dist. Elev.	80.78 39.40	100	38	9	55	51 39	10 39	$\frac{11}{39}$	37	33	88	33 33	8	7 S	38	9	32	8	79.86	9	27	25		8	23	&	79.44 40.42		29.		100
270	Hor. Diff. Dist. Elev.	79.39 40.45	70.97	79.25	79.20 40	79.15 40	79.11 40.	79.06 40.	79.01 40.	78.96 40.	78.92 40.	78.87 40.	78.82 40.	78.77	ó g	78.63	78.58 41.	78.54	78.49		78.34	78.30	78.25	œ́.	78.15	78.10	78.06	78.01		_	5 .89	1
883	Hor. Diff. Dist. Elev.	77.96 41.45	12.72	2	77.77	77.72	79.72	77.62	77.57	77.52	77.48	77.4.7	1.38	3.23	38	77.18	77.13	4.09	2.8	8.8 8.8 8.8	76.89	76.84 42	76.79 42.	76.74 42.	76.69 42	76.64 42.	76.59 42.	76.55 42.	42	98. 99.	_	1 1 1
5%	Hor. Diff. Dist. Elev.	76.50 42.40	76.40	76.35	76.30 42	76.25 42	76.20 42	76.15 42.	76.10 42.	76.05 42.	76.00 42.	75.95 42.	75.90 42.	75.85	75.77	75.70 42	75.65 42.	75.60 42.	75.55 42.	8.5 8.5	75.40	75.35	75.30	75.25 43	75.20	75.15 43.	75.10 43.	75.05 43.27	75.00 43	.65	86.	
် က	Hor. Diff. Dist. Elev.	75.00 43.30	3.5	2.5	2.5	74.75	74.70	74.65	74.60	74.55	74.49	74.44	74.39	7. 2.3	4. F	74.19	74.14	74.09	4.04	73.99	38			73.73	73.68		73.58	73.52		18		3

ELEMENTS OF MECHANICS.

Only the elements of machines are here treated, as all machinery, hower complicated, is merely a combination of the six elementary forms, viz.: er complicated, is merely a combination of the six elementary forms, vize lever, the wheel and auk, the pulley, the inclined plane, the wedge, and screw; and these six can be still further reduced to the lever and the climed plane. They are termed mechanical powers, but they do not be of core; they are only methods of applying and directing it.

The law of all mechanics is:

The power multiplied by the distance through which it moves is equal to the right multiplied by the distance through which it moves.

Thus, 20 lb. of power moving through 5 ft. = 100 lb. of weight moving rough 1 ft. In the following discussion friction is not considered, the eabeing to give an elementary knowledge of the principles of the ements of mechanics.

ements of mechanics.

Levers.—There are three classes of levers. They are: (1) power at one

end, weight at the other, and fulcrum between; (2) power at one end, fulcrum at the other, and weight between; (3) weight at one end, fulcrum

fulcrum at the other, and weight between; (3) weight at one end, fulcrum at the other, and power between.

The handle of a blacksmith's bellows is a lever of the first class. The hand is the power and the bellows the weight, with the pivot between as the fulcrum. A crowbar as used for prying down top rock is a lever of the second class. The hand is the power, the rock to be barred down the weight, and the point in the roof against which the bar presses is the fulcrum. The treadle of a grindstone is a lever of the third class. The foot is the power, the hinge at the back of the foot is the fulcrum, and the moving of the machinery is the weight.

A lever is in equilibrium when the arms balance each other. The distances through which the power and the weight move depend on the comparative length of the arms. Let L represent power's distance from the fulcrum (C). I the weight's distance, and a the distance between power and weight; then, if L is twice l, the power will move twice as far as the weight. Substituting these terms in the law of mechanics, we have





$$\begin{split} P:W::l:L,& PL=Wl,\\ P=\frac{Wl}{L},& W=\frac{PL}{l},\\ l=\frac{Pa}{W+P},& L=\frac{Wa}{W+P}. \end{split}$$

$$P:W::l:L. \quad PL = Wl. \\ P = \frac{Wl}{L}. \quad W = \frac{PL}{l}. \\ L = \frac{Wa}{W-P}. \quad l = \frac{Pa}{W-P}.$$

$$\begin{split} P:W::l:L. & PL = Wl. \\ P &= \frac{Wl}{L}. & W &= \frac{PL}{l}. \\ L &= \frac{Wa}{P-W}. & l &= \frac{Pa}{P-W}. \end{split}$$

In first- and second-class levers, as ordinarily used, we gain power and

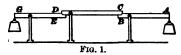
lose time; in the third class, we lose power and gain time.

EXAMPLE.—Having a weight of 2,000 lb. to lift with a lever, the short end of which is 2 ft. from the fulcrum and the long end 10 ft., how much power will be required?

L:l::W:P, or 10:2::2,000:400 lb.

The compound lever, Fig. 1, consists of several levers so constructed the short arm of the first acts on the long arm of the second, and so on

If the distance from A to the fulcrum be four times the distance from t



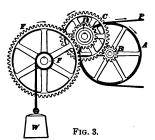
fulcrum to B, then a power 5 lb. at A will lift 20 lb. at If the arms of the second lev are of the same comparati length, the 20-lb. power obtain at B will exert a pressure of lb. on E; and if the third lev

lengths, this 80 lb. at E will lift 320 lb. at G. Thus, a power of 5 lb. A will balance a weight of 320 lb. at G. But, in order to raise the weight ft. the never must receive the weight 1 ft., the power must pass through 330, or 64 ft.

The wheel and axle, Fig. 2, is a modification of the lever. The ordinary windlass is a common form. The power is applied to the handle, the bucket is the weight, and the axis of the windlass is the fulcrum. The long arm of the lever is the handle, and the short arm is the radius of the axle. Thus, F is the fulcrum, Fc the long arm, and Fb the short arm. The wheel and axle has the advantage that it is a kind of perpetual lever. We are not obliged to prop up the weight and readjust the lever, but both arms work continuously.

By turning the handle or wheel around once, the rope will be wound once around the axle, and the weight will be lifted that distance. Applying the law of wheel = the weight × circumference of the axle; or, as the circumference of circles are proportional to their radii, we have





$$P:W::r:R.\ PR=Wr.$$

$$P=\frac{Wr}{R}.\ R=\frac{Wr}{P}.$$

$$W=\frac{RP}{r}.\ r=\frac{RP}{W}.$$

A train, Fig. 3, consists of a series of wheels and axles that act on one another on the principle of a compound lever. The driver is the wheel to which power is applied. The driven, or follower, is the one that receives motion from the driver. The pinion is the small gearwheel on the axle.

If the diameter of the wheel A is 16 in., and of the pinion B 4 in., a pull of 1 lb. applied at P will exert a force of

1 lb. applied at P will exert a force of 4 lb. on the wheel C; if the diameter of C is 6 in., and of D 3 in., a force of 4 lb. on C will exert a force of 8 lb. on E. If E is 16 in. in diameter, and F 4 in., a force of 8 lb. on E will raise a weight of 32 lb. on F. In order, however, to lift this amount, according to the principle already named, the weight will only pass through $\frac{1}{2}$ of the distance of the power. Thus, power is gained and speed lost. To reverse this, we apply power to the axle, and, with a correspondingly heavy power, gain speed. Referring to Fig. 4, applying the

$$P = \frac{Wrr'r''}{R R'R''}, \quad W = \frac{P R R'R''}{r r'r''}, \\ n : n'' :: r'r'' : R R'. \\ v : v' :: r r'r'' : R R'R''.$$

n, n', n'' = number of revolutions;v, v' = v evolution; v, v' = v evelocity or speed of rotation; r, r', r'', etc. = radii of the pinions; R, R', R'', etc. = radii of the wheels.



Fig. 4

The inclined Plane.—In Fig. 5 we see that the power must descend a distance equal to AC in order to elevate the weight to the height BC; hence, we have $P \times$ length of the inclined plane = $W \times$ the height of the inclined plane, or P: W:: height of inclined plane: length of inclined plane; or,

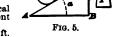
 $=\frac{1}{\sin a}$

To Find the Weight Required to Balance Any Weight on Any Inclined Plane. Multiply the given weight by the sine of the angle of inclination.

Thus, to find the weight required to balance a loaded car weighing 2,000 lb. on a plane pitching 18° , we multiply 2,000 by the sine of 18° , or 2,000 imes

3090170 = 618.034 lb.

Or, if the length of the plane and the vertical height are given, multiply the load by the quotient of the vertical height divided by the length. Thus, if a plane between two levels is 300 ft.



long and rises 92.7 ft., and the load is 2,000 lb., the balancing weight is found as follows:

 $2,000 \times \frac{92.7}{300} = 618 + .$

Case 1.—To find the horsepower required to hoist a given load up an inclined plane in a given time, use the formula

Load (in lb.) + weight of hoisting rope (in lb.) \[\text{vertical height through which the load is raised (in ft.)} \]

 $33.000 \times \text{time of hoisting (in minutes)}$ EXAMPLE.—Find the horsepower required to raise, in 3 minutes, a car weighing 1 ton and containing 1 ton of material up an inclined plane 1,000

ft. long and pitching 30°, if the rope weighs 1,500 lb. The total load equals car + contents + rope = 2,000 + 2,000 + 1,500 =

5.500 lb. The vertical height through which the load is hoisted equals

1,000 × sin 30° = 1,000 × .5 = 500 ft. ∴ H. P. = $\frac{5,500 \times 500}{33,000 \times 3}$ = 27.7.

CASE 2.—When the power acts parallel to the base, use the formula

 $W \times$ height of inclined plane = $P \times$ length of base.

These rules are theoretically correct, but in practice an allowance of about 30% must be made for friction and contingencies.

The screw consists of an inclined plane wound around a cylinder. The inclined plane forms the thread, and the cylinder, the body. It works in a nut that is fitted with reverse threads to move on the thread of the screw. The nut may run on the screw, or the screw in the nut. The power may be

applied to either, as desired, by means of a wrench or a lever

When the power is applied at the end of a lever, it describes a circle of which the lever is the radius r. The distance through which the power passes is the circumference of the circle; and the height to which the weight is lifted at each revolution of the screw is the distance between two of the threads, called the pitch (p). Therefore we have $P \times$ circumference of circle = $W \times$ pitch, or $P : W :: p : 2 \pi r$. $P = \frac{Wp}{W} = \frac{2 \pi r P}{W}$

р

The power of the screw may be increased by lengthening the lever or by diminishing the distance between the

threads.

EXAMPLE.—How great a weight can be raised by a force of 40 lb. applied at the end of a wrench 14 in. long, using a screw with 5 threads per inch? $W \times \frac{1}{4} = 40 \times 28 \times 3.1416$. W = 17,593 lb.

The wedge usually consists of two inclined planes placed back to back. (Fig. 6.) In theory, the same formula applies to the wedge as to the inclined plane, Case 2

P: W:: thickness of wedge: length of wedge.



Friction, in the other mechanical powers, materially diminishes their efficiency; in this it is essential, since, without it, after each blow the wedge would fly back and the whole effect be lost. Again, in the others the power is applied as a steady force; in this it is a sudden blow, and is equal to the momentum of the hammer.

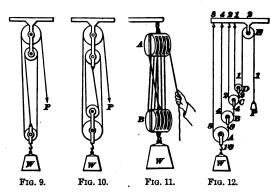
The pulley is simply another form of the lever that turns about a fixed axis or fulcrum. With a single fixed -pulley shown in Fig. 7, there can be no gain of power or speed, as the force P must pull down as much as the weight W, and both move with the same velocity. It is simply a lever of the first class with equal arms, and is used to change the direction of the force.

v = velocity of W. v' = velocity of P. P = W. v = v'.

Movable Pulley.-A form of the single pulley, where it moves with the weight, is shown in Fig. 8. In this, one half of the weight is sustained by the hook, and the other half by the

weight, it must move through twice the space; in other words, by taking twice the time, we can lift twice as much. Here power is gained and time

t. $P=\frac{1}{4}W$. v'=2v. Combinations of Pulleys.—(1) In Fig. 9, we have the W sustained by three cords, each of which is stretched by a tension equal to the P, hence, 1 lb. of power will balance 3 lb. of weight. (2) In Fig. 10, a power of 1 lb. will in the



same manner sustain a W of 4 lb., and must descend 4 in. to raise the W 1 in. (3) Fig. 11 represents the ordinary tackle block used by mechanics, which can be calculated by the following general rule:

Rule.—In any combination of pulleys where one continuous rope is used a load on the free end will balance a weight on the movable block as many times as

great as the load on the free end as there are parts of the rope supporting the load, not counting the free end.

(4) In the cord marked 1, 1, Fig. 12, each part has a tension equal to P; and in the cord marked 2, 2, each part has a tension equal to f P, and so on with the other cords. The sum of the tensions acting on W is 16; hence, W = 16 P. If n = number of pullevs.

Heys, $P=rac{W}{2^n},\;\;W=2^nP.$ Differential Pulley.—Fig. 13. $W=rac{2\,PR}{R-r}.$



In all combinations of pulleys, nearly one-half the effective force is lost friction.

Composition of Forces.—When two forces act on a body at different angles,

eir result may be obtained by the following rule:

Rule. — Through a point draw two lines parallel to the directions of the lines of ction of the two forces. With any convenient scale, measure off, from the point fintersection, distances corresponding to the magnitudes of the respective forces, nd complete the parallelogram. From the common point of application, draw the biggonal of the parallelogram; this diagonal will be the resultant, and its magni-ale can be measured with the same scale that was used to measure the two forces. When more than two forces act on a body simultaneously, find the resultant of any two of them as above; then, by the same method, combine this resultant with a third force, and this resultant with the fourth force, and so on.

FRICTION AND LUBRICATION.

Friction.--Friction is the resistance to motion due to the contact of It is of two kinds, sliding and rolling. If the surface of a body could be made perfectly smooth, there would be no friction; but, in spite of the most exact polish, the microscope reveals minute projections and cavities. We fill these with oil or grease, and thus diminish friction. Since no surface can be made perfectly smooth, some separation of the two bodies must, in all cases, take place in order to clear such projections as exist on the surfaces. Therefore, friction is always more or less affected by the amount of the perpendicular pressure that tends to keep them together.

perpendicular pressure that tends to keep them together.
The ultimate friction is the greatest frictional resistance that one body sliding over another is capable of opposing to any sliding force when at rest.
The coefficient of friction is the proportion that the ultimate friction is given case bears to the perpendicular pressure. The coefficient of friction is usually expressed in decimals; but sometimes, as in the case of cars and engines, it is expressed in pounds (of friction) per ton.

The coefficient of friction equals the ultimate friction divided by the perpendicular pressure, and the ultimate friction equals the perpendicular pressure multiplied by the coefficient of friction. Thus, if we have a block weighing 100 lb. standing on another block, and it takes 35 lb. pressure to slide it the coefficient of friction. slide it, the coefficient of friction = $\frac{3}{100}$, or .35.

TABLE OF COEFFICIENTS OF FRICTION.

Materials.	Smooth, Clean, and Dry Plane Surfaces.	Smooth Plane Surfaces, Perfectly Lubricated With Tallow.
Oak on oak Wrought iron on oak Wrought iron on cast iron Wrought iron on wroughtiron Wrought iron on brass. Cast iron on cast iron Cast iron on brass Steel on cast iron Steel on cast iron Steel on brass Steel on brass Steel on brass Osteel on brass Osteel on brass Steel on brass Steel on brass Osteel on wrought iron Cast iron on oak Steel on wrought iron	.15 .20 .14 .15 .22	.079 .085 .103 .082 .103 .100 .103 .105 .056 .086 .081

The above coefficients are only approximate, for the coefficient will vary with the intensity of the pressure and the velocity, and also with the conditions of the atmosphere. But they are correct enough for practical purposes.

The friction of liquids moving in contact with solid bodies is independent of the pressure, because the forcing of the particles of the fluid over the projections on the surface of the solid body is aided by the pressure of the surrounding particles of the liquid, which tend to occupy the places of those forced over. Therefore, the coefficients of friction of liquids over solids do not correspond with those of solids over solids. The resistance is directly as the area of surface or contact.

COEFFICIENTS OF FRICTION IN AXLES.

Axle.	Bearing.	Ordinary Lubrication.	Lubricated Continuously.
Bell metal	Cast iron Cast iron Lignum vitæ	.097 .07 .07 .07 .07 .07 .10	.049 .05 .05 .05

Friction naturally varies with the character of the surfaces, lubrication, and the nature of the lubricant. The best lubricants for the purposes should always be used, and the supply should be regular. When machinery is well lubricated, the lubricant keeps the surfaces apart, and the frictional resistance becomes very small, or about the same as the friction of liquids.

Frictional Resistance of Shafting.—

K = coefficient of friction;W =work absorbed in foot-pounds;

P = weight of shafting and pulleys + the resultant stress of belts;

H = horsepower absorbed;

D = diameter of journal in inches:

R = number of revolutions per minute.

Then,

ORDINARY OILING.

CONTINUOUS OILING.

 $W = .0182 \times P \times D$: $H = .000000556 \times P \times D \times R;$ $.0112 \times P \times D$: $.000000339 \times P \times D \times R;$.044.

K = .066.

As a rough approximation, 100 ft. of shafting, 3 in. diameter, making 120 revolutions per minute, requires 1 horsepower. For friction of air in mines, see "Coefficient of Friction," under Venti-

lation.

Friction of Mine Cars.—The friction of mine cars varies so much that it is impossible to give a formula for calculating it in every case. No two mine cars will show the same frictional resistance, when tested with a dynamometer, and, therefore, nothing but an average friction can be dealt with. construction of the car, the condition of the track, and the lubrication are important factors in determining the amount of friction.

In this connection, we may, however, state some of the requisites of good oil box and journal bearings. Tightness is a prerequisite, and, in dry mines where the dust is very penetrating, this is especially important; the bearings should be sufficiently broad; the oil box large enough to hold sufficient oil to run a month without renewal, and so constructed that, while it may be quickly and easily opened, it will not open by jarring or by being accidentally struck by a sprag or a lump of coal.

There are a number of patented self-oiling wheels that are improvements on the old-style plain wheels, and each of these has undoubtedly some point of superiority over the old style.

Among the most extensively used of these patented wheels are those with annular oil chambers, and those with patent bushings. Their superiority consists in the fact that, if properly attended to, a well-lubricated bearing is secured with greater regularity and less work than when the old-style wheel was used.

With a view of adopting a standard wheel, the Susquehanna Coal Co., of Wilkesbarre, Pa., experimented for a number of years with different rles of self-lubricating wheels, and as a result of the experiments it adopted

wheel patented by its chief engineer, Mr. Jas. H. Bowden.

Mr. R. Van A. Norris, E. M., Assistant Engineer, made a series of 989 tests ith old-style wheels, some of which had patent removable bushings, and thers annular oil chambers, and the Bowden wheel. The old wheels were bund to be practically alike in regard to friction. All the wheels were of the loose outside type, 16 in. in diameter, mounted on 2\(\frac{1}{2}\) in. steel axles with journals 5\(\frac{1}{2}\) in. long. The axles passed loosely through solid cast boxes, bolted to the bottom sills of the cars, and were not expected to revolve.

The table of friction tests shows the results obtained with both old- and new-style wheels, and is of interest to all colliery managers, inasmuch as the figures given for the old-style wheels alone are the most complete in

existence, and, as stated before, they are good averages.

Tests were made on the starting and running friction of each style of wheel, under the conditions of empty and loaded cars, level and grade track, curves, and tangents. The instruments used were a Pennsylvania Railroad spring dynamometer, graduated to 3,000 lb., with a sliding recorder, a hydraulic gauge (not recording) reading to 10,000 lb., graduated to 25 lb., and a spring balance, capacity 300 lb., graduated to 3 lb. All these were tested and found correct previous to the experiments.

Most of the observations on single cars were made with the 300-lb. ance. The two types of "old-style" wheels have been classed together in Each car was carefully oiled before testing, and several of each the table. type were used, the results being averages from the number of trials shown

in the table.

In the experiments on the slow start and motion, the cars were started very slowly by a block and tackle, and the reading was taken at the moment of starting. They were then kept just moving along the track for a of starting. They were then kept just moving along the track for a considerable distance, and the average tractive force was noted, the whole constituting one experiment.

The track selected for these experiments was a perfectly straight and level piece of 42 in. gauge, about 200 ft. long, in rather better condition than the average mine track. The cars were 41‡ in. gauge, 3½ ft. wheel base, 10 ft.

long, capacity about 85 cu. ft., with 6-in. topping.

To ascertain the tractive force required at higher speeds, trips of one, four, and twenty cars, both empty and loaded, were attached to a mine locomotive and run about a mile for each test, the resistance at various points on the track, where its curve and grade were known, being noted, care also being taken to run at a constant speed. Unfortunately, only four of the "newstyle" cars were available on the tracks where these trials were made

The remarkably low results for the twenty-car trips are attributed to variations in the condition of the track, and the fact that the whole train was seldom pulling directly on the locomotive, the cars moving by jerks, so that correct observations were impracticable. The hydraulic gauge was used for these twenty-car tests, and the needle showed vibrations from 1 to 4 tons The mean was taken as nearly as possible. The gauge was rather too quickly sensitive for the work, and the Pennsylvania Railroad dynamometer was not strong enough to stand the starting jerks and the

strain of accelerating speed.

The tests marked "rope haul" were made on an empty-car haulage system, about 500 ft. long, with overhead endless rope running continuously at a speed of 180 ft. per min., the cars being attached to the moving rope by a chain, a ring at the end of which was slipped over a pin on the side of the The increase of friction on the heavier grades was due to the rope pulling at a greater angle across the car. Correction was not made for this angularity at the time, and the rope has since been rearranged, so that the correction cannot now be made. There were not enough curve experiments to permit the deduction of any general formula for the resistance of these cars on curves.

The experiments on grade agree fairly well with those on a level, the rather higher values obtained being probably due more to the greater effort required in moving them, and the consequent jerkiness of the motion, than to any real increase in resistance. As the experiments on all styles of wheels were made in an exactly similar manner, the comparative value of the results is believed to be nearly correct, the probable error in each set of experiments, as computed by the method of least squares, varying from about 44 for slow start and motion to 12% for the rapid motion and twenty-car trips.

Loaded.		19	23	09	74		18	1		18	16	12			10	10	01-10	-	286			
Empty.		16	63	25	17	က	9	co	10		107	10	15	122	18	10	101	200	276			
Percentage of Weight.					3.32		1.30	1.95			3.94	2.79		E Gree	10	4.70	1.60	1.40	1			
Tractive Force per Ton Due to Friction.		85	1014	583	744		53	44			884 458	62,5			ľ	106	386	25	Total number of tests			
Tractive Force per Car Due to Friction,		325	357	205	262		117	175			311	220		ı side.	177	400	143	170	umbe			
Tractive Force Due to Gravity,							1				1,639	205	1	l fron	1	200	777	7	otal r			
Tractive Force per Car.		325	357	205	262		117	175			1,950	425 pulle		Cars pulled from side.	pulled		pullec		400	143	170	T
Weight of Car.	II.	8.500	7.885	7.885	7,885		9,000	9,000		OE.	7,885	7,885	_	Cars	78.	8,500	0006	2,000	1000			
Percentage of Weight.	LEVEL.	4.46	3.88	2.52	5.89	5.80	2.50	4.29	28.12	GRADE.	3.18	7.00	25.80	5.00	CURVE.	5.58	2.80	4.46				
Tractive Force per Ton Due to Friction,					647						110 68 69	0Z.Z0	252	113	Ņ	125	62	100				
Tractive Force per Car Due to Friction.		100	83	75	62	625	47	96	630		105 66 66	3 8	862	113	1 (5)	125	62	100				
Tractive Force Due to Gravity.											445 645 645	3	800	202				4				
Tractive Force per Car,		100	83	54	62	624	47	96	630		550 510	9	183	315		125	200	100	-			
Weight of Car.		2,240	2,140	2,140	2,140	2,240	2,240	2,240	2,240		2,140 2,140	276	2,240	2,240		2,240	2,240 2,240 2,240	2,240				
Dimensions of Wierels. 16 inches, diameter of tread. 24 inches, diameter of axle. 54 inches, length of journal.		Average slow start.		motion 50 ft. per min	motion 1,000 ft. per min.,	motion 1,000 rt. per min.,	motion 1,000 i	starting jerk,	Average starting jerk, 2 cars, rope naul		Average slow start 12° Average motion 50 ft. per min, 12° Average motion 1 000 ft. ner min 13° 1 car	notion 1,000 ft. per min., 1½°, 1 car	200 ft. per min., rope naul, 20 200 ft. per min., rope haul, 20	notion 200 ft. per min., rope notion 200 ft. per min., rope		low start, 85	rs, 1,000 ft. per min.,	4 cars, 1,000 ft. per min., 350 ft.	THE RESERVE ASSESSMENT OF THE PARTY OF THE P			

FRICTION AND LUBRICATION.

No. of	16868	Empty.		82 48 81 72 6 39		6 12 6 16 16		200		
	No.	Percentage of Weight,		2.20 2.36 1.63 1.93		3.73 1.58 1.85 1.69		3.60		
		Tractive Force per Ton Due to Friction,		49 36 43 10 10		8333 3558 4156 3716		80		
	ed.	Tractive Force per Car Due to Friction.		200 193 158		304 129 151 138		275 325		
	Loaded	Tractive Force. Due to Gravity.				1696 1696 249 212		239		
EELS.	Inci-	Tractive Force.			200 193 153 158		2,000 1,825 400 350		275 564	
NEW-STYLE WHEELS.	Salari y	Weight of Car.		8,160 8,160 8,160 8,160	E.	8,160 8,160 8,160 8,160	т.	9,125		
-STYLE	y Les	Percentage of Weight.	LEVEL.	2.78 2.48 1.66 1.56	GRADE	4.06 1.56 1.12	CURVE.	0 0		
NRV	131	Tractive Force per Ton Due to Friction.		8337-15 3415		90 10 25 10		5		
	Empty.	Tractive Force per Car Due to Friction.		662 40 368 371 871		98 38 27		u L		
	Emj	Tractive Force Due to Gravity.				502				
		Tractive Force per Car.		663 62 40 365 375		600 540 100				ì
		Welght of Car.		2,415 2,415 2,415 2,415 2,415		2,415 2,415 2,415		20		
NEW-STYLE WHEELS.		DIMENSIONS OF WHERLS. 16 inches, diameter of tread. 24 inches, diameter of axle. 54 inches, length of journal.		Average slow start Average motion 1,000 ft. per min. Average motion 1,000 ft. per min. 1 car Average motion 1,000 ft. per min. 4 cars		Average slow start 120. Average motion 50 ft. per min., 120. Average motion 1,000 ft. per min., 119.1 car. Average motion 1,000 ft. per min., 119.1 car.		Average slow start, 85 ft. radius.		

Lubrication.—There is probably no factor that has a more direct bearing on the cost of production per ton of coal and ores than the lubrication of mine machinery, and yet it is doubtful if there is another item connected with the operation of a mine less understood by owners, their managers, and

engineers in charge.

Steam plants are equipped with boilers of the highest known efficiency; heaters are used that, by utilizing waste steam, will heat the feedwater for boilers to the highest point. Modern engines that will develop a horsepower with the least amount of steam are installed; bends, instead of elbows, are placed in steam and exhaust pipes, so that the friction and back pressure may be reduced to a minimum. In a word, everything is done in the equipment of a plant to secure economy in its operation. After all this is done, ment of a plant to secure economy in its operation. After all this is done, frequently a long step is taken in the opposite direction by the use of an oil unsuited to the existing conditions, and those in charge of the plant are led to believe that the lubrication is all that could be desired, simply because the engines and machinery run quietly and the temperature of the bearings does not become alarmingly high. The office of a lubricant is not merely to secure this result, but, primarily, to reduce friction and wear to a minimum; and an oil that will do this is the best oil to use, no matter what the price realled may be per gallon may be.

Few realize the great loss in power due to the friction of wearing parts. One of the greatest living authorities on lubrication writes:

"It may probably be fairly estimated that one-half the power expended in the average case, whether in mill, mine, or workshop, is wasted on lost work, being consumed in overcoming the friction of lubricated surfaces."

He adds that a reduction of 50% in the work lost by friction has often been

secured by a change of lubricants.

As one of many instances showing the loss that will occur by the use of inferior lubricants, attention is called to two flour mills located in one of the Middle States. One of the plants was equipped with a condensing engine capable of developing a horsepower on 24 lb. of water per hour; the other plant had a simple engine, taking 30 lb. of water per hour. The plant containing the condensing engine was purchased by the owner of the plant containing the simple engine. The new owner of the plant was surprised to learn that the cost of operation per barrel of flour manufactured was equally as great in the new plant as in the old one. The engines were indicated, and valves found to be properly adjusted and the engine working within the economical range, so far as load was concerned. The loss was then attributed to the boilers, but an evaporative test proved that there was no practical difference here, as the boilers, in both instances, were evaporating a fraction over 8 lb. of water per pound of coal. At this point, the question of lubrication was taken up, and, on the advice of an expert sent by a prominent manufacturer of lubricants to look over the plant, an entire change was made in the lubricants used, and, as a result, a money saving of cours 30.5 per day (practically \$700 per annum, this in, alant of least sent by a part of least sent the lubricants used, and, as a result, a money saving of over \$2.25 per day (practically \$700 per annum—this in a plant of less than 250 horsepower) was effected, notwithstanding the fact that the new lubricants used cost considerably more per gallon than those formerly used. This simply indicates that the price of an oil is of little importance in comparison with its friction-reducing power. Friction to means greater cost of operation per unit of output. Friction costs money, because

Among the expenses chargeable to waste power, due to inferior lubrica-tion, may be included: (1) The cost of power produced in excess of that really required to operate the mine per ton of output. In this calculation should be included the proper proportion of salaries of engineers, and all other items that contribute to the cost of the motive department, as well as the cost of mining the fuel consumed in producing this excess power.

(2) Wear and tear of machinery, which is constantly doing more work per ton of coal mined than should be required of it.

There is also an element of danger that ought to receive serious consideration, as, while it is true that cylinder and bearing lubricants of indifferent merit will, under ordinary conditions, keep the cylinders from groaning and the bearings from becoming hot, experiments have proved that, in accomplishing such results, the oils in use were being taxed to their utmost; and there is record of many instances where, as a result of using oils of such limited endurance, accidents of a serious nature have occurred, necessarily causing shut-downs just at the time when the operation of a plant to its fullest capacity was imperative.

It is most difficult, in an article of this character, to do much more than

point out the danger due to the use of inferior lubricants, leaving it to the purchaser himself to determine as to the intrinsic worth of the lubricants offered to him. In making his selection he would do well to consult with and heed the advice of some highly responsible manufacturer of lubricants who has given to the question, in all its phases, the most careful study, and who would most probably have the benefit of a wide experience in the application as well as the manufacture of lubricants. Some buyers have, to their ultimate regret, adopted, as a method of determining the merits of lubricants, a schedule of laboratory tests. Such a method is not only useless, but it is misleading to any one other than a manufacturer of lubricants, who makes use of it merely as a means of insuring uniformity in his manufactured products, and not as a measure whereby to judge their practical value. Indeed, many oils can be very properly described by practically the same schedule of tests, and yet are widely apart when their utility for a given service is considered.

As a general guide in purchasing cylinder oil for mine lubrication, it might be said that a dark-colored oil is of greater value, as a rule, than one that has been filtered to a red or light amber color, as the process of filtration necessarily takes from the oil a considerable percentage of its lubricating value, and at the same time the process is an expensive one. In short, if a light-colored oil is insisted upon, a high price must be paid for an inferior lubricant. As a word of caution, however, it would be well to add right here that irresponsible manufacturers frequently take advantage of the fact that the most efficient and best known cylinder oils are dark-colored, and endeavor, with more or less success, to market as "cylinder oil" products absolutely unsuited to the lubrication of steam cylinders, and that would

consequently be expensive could they be procured without cost.

For the lubrication of engine bearings, where modern appliances for feeding are used, an engine oil of a free running nature is best, as it more quickly reaches the parts requiring lubrication than an oil of a more sluggish nature. It, of course, must not be an oil susceptible to temperature changes, but must be capable of performing the service required of it under the most severe conditions, where an oil of less "backbone" would fail. Such an oil would also be suitable for the lubrication of dynamos, and should also give satisfaction where used in lubricating the cylinders of air compressors. where the machinery is of an old type and loose-jointed, or when the bearings are open and the oil is applied directly to them by means of an oiler, an engine oil of a more sluggish, or viscid, nature is best.

Perhaps of equal importance to the lubrication of power machinery must be considered the lubrication of the axles of mine cars. This is

important, first, because of the fact that perhaps three-fourths of the oil used about a coal mine is used for this purpose, and, secondly, because there is really a marked difference in the quality and, therefore, in the efficiency of lubricants used for this purpose. Fully nine-tenths of the prominent railroads of this country are today using car-axle oil, costing perhaps as much per gallon as much of the so-called cylinder oil that is used in coal mines, they having discovered, by exhaustive experiments, that the increased efficiency gained by using an oil of such quality many times offsets the difference in the cost per gallon and enables them to secure a greater mileage without any increase in their power or other fixed charges. This, we are certain, would apply just as forcibly to the lubrication of coal cars, no matter whether the power is derived from "long-eared mules" or electric motors, and we believe this feature of lubrication of mine equipment should

receive more careful attention than it does receive, as a rule.

There is a considerable amount of waste in the lubrication of mine cars. This waste is hard to avoid, and, naturally, makes the buyer hesitate before adopting the use of a car oil that costs very much per gallon; but we believe it can be demonstrated, even in the face of this waste, that the increased efficiency secured by the use of a high-grade car oil would warrant its use. Such waste is pretty hard to correct in mines where the old-fashioned style of car axles is still in use, and where the oil is applied through an ordinary spout oil can into the axle box, and allowed to drip off the axles and on to the ground. When axles are equipped in the same manner as those of freight cars, or where cars are equipped with one of the several different styles of patent car wheels and axles that are coming into use quite extensively, it is possible to regulate the feeding of the oil to the axles, so as to reduce the waste to a minimum. One of these patent car wheels, which is perhaps better known than any other, is constructed with a hollow hub

that acts as a reservoir for the oil, the oil passing from this reservoir through small holes onto a felt washer, which it must saturate, and by which it is applied to the axles. Such wheels require a limpid oil, as a heavy, sluggish oll would not so readily saturate the felt washer referred to. A tight cap is adjusted to the end of the axle, to prevent waste of oil. These wheels will run quite a length of time without reolling after the reservoir is once filled.

Of course, it costs something to equip mine cars with these patent axles, but we are convinced that such an outlay would result in more economical operation, particularly if at the same time the very best quality of car oil

obtainable is used.

PECT LUBBICANTE FOR DIFFERENT BURBOCES (THURSTON)

BEST LUBRICANIS FOR DIFFERE	NI PURPOSES (THURSTON).
Low temperatures, as in rock drills driven by compressed air	right mineral indicating offs.
Very great pressures, slow speed	Graphite, soapstone, and other solid lubricants.
Heavy pressures, with slow speed	The above, and lard, tallow, and other greases.
Heavy pressures and high speed	Sperm oil, castor oil, and heavy mineral oils.
Light pressures and high speed	Sperm, refined petroleum, olive, rape, cottonseed.
Ordinary machinery	Lard oil, tallow oil, heavy mineral oils, and the heavier vegetable oils.
Steam cylinders	Heavy mineral oils, lard, tallow.
Watches and other delicate mechanism.	Clarified sperm, neat's foot, por- poise, olive, and light mineral lubricating oils.
For mixture with mineral oils, sperm	i is best; lard is much used; olive

and cottonseed are good.

STRENGTH AND WEIGHT OF MATERIALS

WOODEN BEAMS.

To find the Quiescent Breaking Load of a Horizontal Square or Rectangular Beam Supported at Both Ends and Loaded at the Middle.—Multiply the breadth in inches by the square of depth in inches, divide the product by distance in feet between the supports, and multiply the quotient by the constant given in the table on the next page. Take safe working load one-third of breaking load.

To Find the Quiescent Breaking Load of a Horizontal Cylindrical Beam.—Divide the cube of the diameter in inches by the distance between the supports in

fect, and multiply the quotient by the constant.

When the load is uniformly distributed on the beam, the results obtained by the above rules should be doubled.

EXAMPLE 1.—Find the quiescent breaking load and safe working load of a yellow-pine collar 8 in. square, 12 ft. between legs.

Breaking load = $\frac{8 \times 8^2}{12} \times 500 = 21,333$ lb. for seasoned, and 10,666 lb. for green timber.

Safe working load = 7,111 lb. for seasoned, and 3,556 lb. for green timber. EXAMPLE 2.—Find the quiescent breaking load, and the safe working load of a hemlock collar 10 in. diameter, 7 ft. between legs.

Breaking load = $\frac{10^3}{7} \times 236 = 33,714$ lb. for seasoned timber, and $\frac{33,714}{9}$

= 16,857 lb. for green timber.

Safe working load = $\frac{33,714}{2}$ = 11,238 lb. for seasoned, and $\frac{33,714}{6}$ or $\frac{11,238}{2}$

= 5,619 lb. for green timber.

To Find the Load a Rectangular Collar Will Support When its Depth is increased. When the length and width remain constant, the load varies as the square of the depth.

EXAMPLE.—A rectangular collar 10 in. deep supports 15,000 lb. What will support if its depth is increased to 12 in.?

104: 122:: 15,000: 21,600. Ans.

Having the Length and Diameter of a Collar, to Find the Diameter of a Longer Collar, bapport the Same Weight.—For the same load, the strength of collars varies at the cubes of their diameters, and inversely as their lengths.

EXAMPLE.—If a collar 6 ft. long and 8 in. diameter supports a certain reight, what must be the diameter of a collar 12 ft. long to support the same weight?

Or

 $\sqrt[4]{6}:\sqrt[4]{12}:8$ in.: 10+ in. Ans. Having the Loads of Two Beams of Equal Length and the Diameter of One, to find the Diameter of the Other.—When the lengths are equal, the diameters vary as the cube roots of the loads, or the cubes of the diameters vary as the loads.

EXAMPLE 1.—A beam 11 in. in diameter supports a load of 32,160 lb. What will be the diameter of another beam the same length, to support a load of 19.440 lb.?

 $\sqrt[4]{32,160}$: $\sqrt[4]{19,440}$:: 11:9. Ans.

EXAMPLE 2.—A beam 8 in. in diameter will support a load of 10,240 lb. What load will a beam the same length and 7 in. in diameter support? 83:73::10,240:6,860. Ans.

TABLE OF CONSTANTS.

Calculated for seasoned timber. For green timber, take one-half of these constants. Safe working load is one-third of breaking load.

Woods.	Square or Rectan- gular.	Round.	Woods.	Square or Rectan- gular.	Round.
Ash, white	650	383	Locust	600	353
Ash, swamp	400	236	Lignum vitæ	650	383
Ash, black	300	177	Larch	400	236
Balsam, Canada	350	206	Maple	550	324
Beech, white	450	265	Oak, red or black	550	324
Beech, red	550	324	Oak, white	600	353
Birch, black	450	265	Oak, live	600	353
Birch, yellow	450	266	Pine, white	450	265
Cedar, white	250	147	Pine, yellow	500	295
Chestnut	450	265	Pine, pitch	550	324
Para	350	206	Poplar	550	324
Min, rock	600	353	Spruce	450	265
Hemlock	400	236	Sycamore	500	295
Hickory	650	383	Willow	350	206
Ironwood	600	353		"	200

To Find the Diameter of a Collar When the Weight Increases in Proportion to the length.—Find the required diameter to support the same weight as the short collar. Then the length of the short collar is to the length of the long one as the diameter found to support the original weight is to the required diameter.

EXAMPLE.—If a collar 6 ft. long, 8 in. in diameter, supports a certain weight, what must be the diameter of a collar 12 ft. long to support twice the weight?

1:2::
$$\frac{8^3}{6}$$
: $\frac{()^8}{12}$, or 1:2::2×8³:()³, $\sqrt[8]{1}$: $\sqrt[8]{2}$::8 $\sqrt[8]{2}$:() = 12.7. Ans.

IRON AND STEEL BEAMS.

Constants for use in calculating strength of iron and steel beams:

	
Cast iron	2.000
Wrought iron	2 200
Steel	5,000
Steet	0,000

SAFE LOADS UNIFORMLY DISTRIBUTED FOR STANDARD AND SPECIAL I BEAMS.

(Tons of 2,000 Pounds.)

ery Lb. Weight.	Add for Ev Increase in	.16	.13	11.	.10	6 9.	8	.07	.07	99.	8	3	පි	9	3	ġ	₹.	Į.			
3″ I.	5.5 Lb.	1.76	1.47	1.26	1.10	98.0	98.0	0.80	0.73	89.0	0.63	0.59	0.55	0.52	0.49	0.46	0.44	0.43			
ery I.b. Weight.	vd tot bbA ni sessioni	됨	.18	.15	.13	.12	Ξ.	.10	8	89.	89	6.	6	8	8	8	39	8			
4″ I.	7.5 Lb.	3.18	2.65	2.27	1.99	1.72	1.59	1.45	1.33	1.22	1.14	1.06	66.0	3.0	88	8.0	8 .0	92.0			
ery Lb. Weight.	Add for Ev Increase in	.26	8	19	91.	.14	.13	.12	Ξ.	01.	8	S.	89	8	6.	6.	6.	8			
5″ I.	9.75 Lb.	5.16	4.30	3.69	3.23	2.87	2.58	2.35	2.15	1.98	1.82	1.72	1.61	1.52	1.43	1.36	1.29	1.3		_	
ery Lb. Weight.	Add for Ev ni seastani	.33	97.	જ	10	.17	91.	.14	.13	.12	Η.	97	9	S;	8	89.	80.	-02			
6′. I.	12.25 Lb.	7.75	6.46	5.54	4.84	4.31	3.88	3.52	3.23	2.98	2.77	2.58	2.45	23	2.15	7.0 <u>7</u>	1. 22.	1.85		_	400
ery Lb. Weight.	Add for Ev ni əzsətəni	8.	8.	97	গ্ন	8	.18	.16	.15	.14	.13	21.	Ξ	Ε.	97.	8	8	8			1
7". I.	15 Lb.	11.04	9.30	7.89	6.90	6.13	5.52	5.05	4.60	4.25	3.94	3.68	3.45	3.25	3.07	2.91	2.76	2.63			8
ery Lb. Weight.	Add for Ev ni essetin	24:	38.	.30	83.	ध	17.	91.	.18	.16	.15	14	55	77	27.	Ξ.	=	9			
8″ I.	18 Lb.	15.17	12.64	10.84	9.48	8.43	7.59	6.90	6.32	5.83	5.45	90.9	4.74	4.46	4.21	3.99	3.79	3.61			10
etween n Feet.	Distance B Supports in	2	9	7	œ	6	91	=	12	13	7	15	91	17	81	19	ន	2			
ery Lb. Weight.	Add for Ev Increase in	8.	.18	.17	91.	.15	.14	.13	.12	.12	Ξ.	Ξ.	9	9	8	8	ද	8	8	8	3.6
9′ I.	21 Lb.	8.39	7.74	7.19	6.71	6.29	5.92	5.59	5.30	5.03	4.79	4.58	4.38	4.19	4.03	3.87	3.73	3.59	3.47	3.36	
	va tot bbA ni serstani	ध	8	.19	.17	91.	.15	.14	.14	.13	.12	.12	Ξ.	Ξ.	2.	9	97.	S;	8	8. -	4.4
10″ I.	25 Lb.	10.85	10.02	9.30	8.68	8.14	7.66	7.24	98.9	6.51	6.20	5.93	99.9	5.43	5.21	5.01	4.85	4.65	4.49	4.34	Am after S. was a land
ery Lb. Weight.	Add for Ev Increase in	.26	1 2.	क्ष	.21	.20	.19	.18	.17	91.	.15	.14	.14	.13	.13	77	.13	=	Ε.	Η.	
ï	31.5 Lb.	15.99	14.76	13.70	12.79	11.99	11.29	10.66	10.10	9.59	9.14	8.7.5	8.34	33	7.67	7.38	7.11	6.85	6.62	6.40	of the co
12″	Lb.	19.92	18.39	17.08	15.94	14.94	14.06	13.28	12.58	11.95	11.38	10.87	10.39	96.6	9.56	9.19	8.85	8.54	8.24	7.97	fo loads
	A esanat si O ii stroqqu2	2	13	7	15	16	12	18	19	ଛ	21	3	গ্ন	75	ধ্ব	8	2	88	~ 않	ၕ	Gofo

Safe loads given include weight of beam. Maximum fiber stress, 16,000 lb, per sq. in. For specings below the heavy lines, the dedections will be greater than the allowable lim

Hard steel will break the same as cast iron. Soft steel will bend like wrought iron. The elastic limit of wrought iron is reached at about 2,200 lb.

As it does not break, we use the limit of elasticity.

To find the Quiescent Breaking Load of a Horizontal Square or Rectangular from or Steel Beam Supported at Both Ends and Loaded at the Middle.—Multiply the square of its depth in inches by its breadth in inches; multiply this result by the constant for the material used, and divide by the length in feet between the supports. For the neat load, subtract one-half the weight of the beam.

To Find the Quiescent Breaking Load of a Cylindrical Iron or Steel Beam. Find the breaking load of a square beam the sides of which are equal to the

diameter of the round one, and multiply by .6.

Safe working load in each of the preceding cases is one-third of the breaking load. If the load is equally distributed over the beam, it will be twice as great.

PILLARS OR PROPS.

To Find the Crushing Load of Eithor Square or Roctangular Wooden Pillars or Props.—Call one side of the square or the least side of the rectangle the breadth. Divide the square of the length in inches by the square of the breadth in inches, multiply the quotient by .004, add I to the product, and divide the constant in the following table by the result. Then multiply this quotient by the number of square inches in the end of the prop.

Or, breaking load in lb. =
$$\frac{\text{Constant}}{\left(\frac{l^2}{b^2} \times .004\right) + 1} \times b d,$$

when l = length in inches, b = length in inches, and d = length in inches. CRUSHING LOADS OF WELL-SEASONED AMERICAN WOODS.

Wood.	Crushing Load. Lb. per Sq. In.	Wood.	Crushing Load, Lb, per. Sq. In.
hah Boach Broth Cedar, red Cedar, white Chasinut Hickory Linden Locas, black, yellow Locas, honey Maple, broad-leafed Oregon	6,800 7,000 8,000 6,000 4,400 5,300 8,000 5,000 9,800 7,000 5,300	Maple, sugar, black Maple, white, red Oak, white, red, black Oak, scrub, basket Oak, chestnut, live Oak, pin Pine, white Pine, pitch Pine, Georgia Poplar Spruce, black Spruce, white Willow	8,000 6,800 7,000 6,000 7,500 6,500 5,400 5,000 8,500 5,700 4,500 4,400

For green timber, take one-half of the constants or crushing strength. Safe working load equals one-third of crushing load.

EXAMPLE.—What is the breaking load of a well-seasoned hemlock post 10 in. by 8 in. and 12 ft. long?

 $5,300 \div \left[1 + \left(\frac{144^2}{8^2} \times .004\right)\right] = 2,308.4 \text{ lb. per sq. in. of area.} \quad 2,308.4 \times 80$

 $= 184,672 \, l\bar{b}.$ To find the Breaking Load of a Cylindrical Wooden Prop.-Find the breaking load of a square prop whose ends are equal in area to those of the cylin-

drical one, and proceed according to foregoing rule.

EXAMPLE.—What is the safe working load for a hemlock mine prop 10 in.

diameter, 10 ft. long?

The area of the end of the prop = 78.54 sq. in. A square of equal area

will have sides equal to $\sqrt{78.54} = 8.86 + \text{in}$. Then, $5,300 \div \left[1 + \left(\frac{120^2}{8.86^3} \times .004\right)\right] = 3,058.3 \text{ lb. per each sq. in. of area.}$

And $3,058.3 \times 78.54 = 240,198$ lb. This is the crushing strength of a similar And 0,000.0 × 10.04 = 240,130 10. This is the crushing strength of a similar prop of seasoned timber, but, as mine timber is used in its green state, we take one-half of 240,198 lb., or 120,099 lb., as the crushing load of the prop in question. Then, the safe working load is one-third of this, or 40,033 lb.

The strength of similar props varies as the cubes of their diameters, and

inversely as their lengths.

SAFE LOADS, IN TONS OF 2,000 POUNDS, FOR HOLLOW CYLINDRICAL CAST-IRON COLUMNS.

(The Carnegie Steel Co., Limited.)

100	Jo s			Le	ngth o	f Colu	mns in	Ft.			Area.	Lb. of per
inches.	Thickness of Metal.	8	10	12	14	16	18	20	22	24	Sectional Area. Inches.	Weight in Columns Ft. of Lea
-	Thi	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Sect	Weig Col
3	1	26.2	23.0	20.1	17.5	15.2 21.7	13.2 18.9	11.5	in 2 milying	7 1 10	8.6	26.95
6	1 3 4 7 a	37.5	33.0	28.8	25.0	21.7	18.9	16.5		C-1023	12.4	38.59
;	7 8	42.7	37.6	32.8	28.5	24.7	21.5	18.8	0.000	-10	14.1	43.96
3	1	47.6	41.9	36.5	31.8	27.6	24.0	21.0			$15.7 \\ 17.2$	49.01
	11/8 3	52.2 47.7	46.0	40.1	34.8	30.2	26.3	23.0 23.9	21.2	18.9	14.7	53.76 45.96
	1 4	41.7	43.1	38.5 49.3	34.3 43.8	30.4 38.9	26.9 34.4	30.6	27.1	24.2	18.9	58.90
	1	61.1 67.2	55.2 60.8	54.3	48.3	42.8	37.9	33.7	29.9	26.7	20.8	64.77
	1183	57.9	53.3	48.6	44.1	39.7	35.8	32.2	28.9	26.1	17.1	53.29
	1	74.6	68.7	62.5	56.7	51.1	46.0	41.4	37.3	33.6	22.0	68.64
3	11	89.9	82.8	75.5	68.4	61.7	55.5	49.9	44.9	40.5	26.5	82.71
1	11/4	68.1	82.8 63.6	58.9	54.2	49.6	45.2	41.2	37.5	34.1	19.4	60.65
)	1	88.0	82.3	-76.2	70.0	64.1	58.4	53.2	48.4	44.1	$25.1 \\ 30.4$	78.40 94.94
9	1½ 1½	106.6	99.6	92.2	84.8	77.6	70.8	64.4 74.8	58.7 68.1	53.4 62.0		110.26
	13	123.8	115.7	107.1 120.8	98.5 111.1	90.1 101.6	82.2 92.7	84.4	76.8	69.9	39.9	124.36
)	1 ³ / ₄	139.6 101.4	130.5 95.9	89.8	83.6	77.4	71.5	65.8	60.5	55.5	28.3	88.23
)	114	123.3	116.5	109.1	101.6	94.1	86.8	79.9	73.4	67.5	34.4	107.23
)	11	143.7	135.8	127.3	118.5	109.7	101.2	93.2	85.6	78.7		124.99
)	13	162.7	153.8	144.1	134.1	124.2	114.6	105.5	97.0	89.1		141.65
	1	114.8	109.4	103.5	97.3	91.0	84.8	80.2	73.1	67.7	31.4	98.03 119.46
	11/4	139.9	133.3	126.1	118.6	110.9	103.3 120.8	97.8 114.3	89.4 104.1	82.5 96.4	44 8	139.68
	$\frac{1\frac{1}{2}}{1\frac{3}{4}}$	163.5 185.7	155.9 177.1	$147.5 \\ 167.5$	138.6 157.5	128.7 147.3	137.2	129.8	118.3	109.5	50.9	158.68
1	2	206.6	196.9	186.3	175.1	163.8	152.6	144.4	131.5	121.8		176.44
2	1	128.0	122.9	117.2	111.0	104.7	98.4	92.2	86.1	80.4	34.6	107.51
2	14	156.4	150.1	143.1	135.7	127.9	120.2	112.6	105.2	98.2	42.2	131.41
2	11/2	183.3	175.9	167.7	159.0	149.9	140.9	132.0	123.3	115.1	49.5	154.10
2	13	208.7	200.4	191.0	181.1	170.7	160.4	150.3	140.5	131.1	60.4	175.53 195.75
2	2	232.7	223.4	213.0 130.7	201.9	190.4 118.5	178.9	167.6 105.8	156.6 99.5	146.1 93.5	37 7	117.53
3	1	141.2 172.8	136.3 166.8	160.0	$124.7 \\ 152.7$	145.0	$112.1 \\ 137.2$	129.4	121.8	114.4		143.86
3	1 ¹ / ₄ 1 ¹ / ₂	203.0	195.9	187.9	179.3	170.3	161.1	152.0	143.1	134.3	54.2	168.98
3	13	231.6	223.6	214.5	204.7	194.4	183.9	173.5	163.3	153.3	61.9	192.88
3	2	258.9	249.9	239.7	228.7	217.3	205.5	193.9	182.5	171.3	69.1	215.56
4	1	154.3	149.6	144.3	138.5	132.3	125.9	119.5	113.1	106.8	40.8	127.60
4	114	189.2	183.4	176.9	169.7	162.2	154.4	146.5	138.6	131.0 154.1	1.06	156.31 183.67
4	11	222.6	215.8	208.1	199.7	190.8	181.7 207.6	172.3 197.0	163.1 186.5	176.2	67.4	210.00
4	13	254.4 284.8	246.7	237.9 266.4	228.3 255.6	218.1 244.2	232.4	220.6	208.8	197.2		235.12
5	2	284.8 167.4	276.2 162.9	157.8	152.1	146.0	139.7	133.3	126.8	120.4		137.28
5	114	205.5	200.0	193.7	186.7	179.3	171.5	163.6	155.7	147.9		168.48
5	11/2	242.1	235.7	228.2	220.0	179.3 211.2	202.1	192.8	183.5	174.2	63.6	198.74
5	13	277.2	269.8	261.3	251.9	241.9	231.4	220.7	210.1	199.5	72.9	227.45
5	2	310.8	302.5	293.0	282.5	271.2	259.5	247.5	235.5	223.6	81.7	254.90

MINIMUM SAFE-BEARING VALUES OF MASONRY MATERIALS.

Materials.	Tons per Sq. Ft.
Franite, capstone	50
Squared masonry	25
Sandstone, capstone	25
Squared masonry	12
Rubble, laid in lime mortar	5
Rubble, laid in cement mortar	10
Limestone, capstone	36
Squared masonry	
Rubble, laid in lime mortar	5
Rubble, laid in cement mortar	10
Bricks, hard, laid in lime mortar	7
Hard, laid in Portland cement mortar	14
Hard, laid in Rosendale cement mortar	10
Concrete, 1 Portland, 2 sand, 5 broken stone	10

SPECIFIC GRAVITY, WEIGHT, AND PROPERTIES OF MATERIALS, ETC.

The specific gravity of a body is the ratio of its weight to the weight of an equal bulk of pure water, at a standard temperature (62° F. = 16.670° C.).

Some experimenters have used 60° F. as the standard temperature, others 32° and still others, 39.1°. To reduce a specific gravity, referred to water

at 39.1° F., to the standard of water at 62° F., multiply by 1.00112.

Given specific gravity referred to water at 62° F., multiply by 62.355 to find the weight of a cubic foot of the substance. Given weight per cubic foot, to find specific gravity, multiply by 0.016037.

Given specific gravity, to find the weight per cubic inch, multiply by

aver specific gravity, to find the weight per cause men, manufact by

0.036085.

To Find the Specific Gravity of a Solid Heavier Than Water.—Weigh the body both in air and in water, and divide the weight in air by the difference of the weights in air and water.

Example.—A piece of coal weighs, say, 480 grains. Loss of weight when weighed in water, 398 grains.

Then, 489 = 1.206, specific gravity of the coal compared with water at

.000.

As a cubic foot of water weighs, approximately, 1,000 oz., the weight of a

cubic foot of any substance can be found by multiplying its specific gravity by 1,000.

To find the Specific Gravity of a Solid Lighter Than Water.—Attach to it another body heavy enough to sink it; weigh severally the compound mass and the heavier body in water, divide the weight of the body in air by the weight of the body in air plus the weight of the sinker in water minus the combined weight of the sinker and body in water.

To Find the Specific Gravity of a Fluid.—Weigh both in and out of the fluid a solid (insoluble) of known specific gravity, and divide the product of the weight lost in the fluid and the specific gravity of the solid by the weight of

the solid

The weight of a cubic foot of water at a temperature of 62° is about 1,000 oz. avoirdupois, and the specific gravity of a body, water being 1,000, shows the weight of a cubic foot of that body in ounces avoirdupois. Then, if the magnitude of the body be known, its weight can be computed; or, if its weight be known, its magnitude can be calculated, provided we know its specific gravity; or, of the magnitude, weight, and specific gravity, any two being known, the third may be found.

To Find the Magnitude of a Body in Cubic Feet From Its Weight.—Divide the weight of the body in ounces by 1,000 times the specific gravity of the body.

To Find the Weight of a Body in Ounces From Its Magnitude.—Divide the weight of the body in ounces by the specific gravity of the substance multiplied by 1,000.

Note.—The specific gravity of any substance is equal to its weight in grams per cubic centimeter. (See table of metric weights and measures.)

SPECIFIC GRAVITY OF SUBSTANCES.

Substance.	Average Specific Gravity.	Average Weight pe Cu. Ft. Lb
Air, atmospheric; at 60° F. under pressure of 1 at-		
mosphere, or 14.7 lb. per sq. in	.00123	.0765
Alcohol, pure	.793	49.43
Alcohol, of commerce	.834	52.1
Aluminum	2.66	166.0
Anthracite* coal	1.5	93.5
Asphaltum	1.4	87.3
Brass, cast	8.1	504.0
Brass, rolled		
Drame, cum motol	8.4	524.0
Bronze, gun metal	8.5	529.0
Brick, best pressed		150.0
Brick, common hard	ł	125.0
Carbonic-acid gas	.00187	.1167
Clay, dry, in lumps, loose	1	63.0
Clay, potters', dry	1.9	119.0
Coke, floose, of good coal	1.0	27.5
Coal, bituminous :	1.35	84.0
Coal, bituminous, broken loose	1.50	
Cool bituminous, proken 100se	1	50.0
Coal, bituminous, moderately shaken	1 '	54.0
Copper, cast	8.7	542.0
Copper, rolled	8.9	555.0
Cork	.25	15.6
Earth, common loam, perfectly dry, loose		76.0
Earth, common loam, perfectly dry, shaken	i	87.0
Earth, common loam, perfectly dry, moderately packed		95.0
Earth, common loam, slightly moist, loose	Ī	78.0
Earth, common loam, more moist, loose		80.0
Earth, common loam, more moist, shaken		
Forth common learn more moist, shaken	į.	90.0
Earth, common loam, more moist, packed	l	96.0
Earth, common loam, as a soft flowing mud	į.	108.0
Earth, common loam, as a soft mud packed		115.0
Gold, cast, pure or 24 carat	19.26	1,204.0
ravel		98.0
łutta percha	.98	61.1
Sypsum (plaster of Paris)	2.27	141.6
lypsum, in irregular lumps		82.0
Sypsum, ground, loose		56.0
Impum ground well shelten	l .	
ypsum, ground, well shaken ypsum, calcined, loose	l	64.0
y psum, carcined, loose		56.0
Hydrogen gas, 141 times lighter than air and 16 times	!	
lighter than oxygen		.00527
ce	.92	57.4
ron, cast	7.21	450.0
ron, rolled bars	7.65	480.0
ron, sheet	7.00	485.0
ron, wrought	7.77	485.0
ead		
imo aviole	11.38	709.6
ime, quick	1.5	95.0
ime, quick, ground, loose, per struck bushel, 66 lb.		53.0
Mercury, at 32° F. Mercury, at 60° F.	13.62	849.0
Mercury, at 60° F	13.58	846.0
Mercury, at 212° F	13.38	836.0
Nitrogen gas, 3x part lighter than air		.0744
Dils, whale, olive	.92	57.3
		U1.U

^{*}Anthracite increases about 75 per cent. in bulk when broken to any market size. A ton loose, averages from 40 to 45 cu. ft.

'A heaped bushel, loose, weighs from 35 to 42 lb. A ton occupies 80 to 97 cu. ft.

'A heaped bushel, loose, weighs about 74 lb., and a ton occupies from 43 to 48 cu. ft. Bituminous coal, when broken, occupies 75 per cent. more space than in the solid.

SPECIFIC GRAVITY OF SUBSTANCES—(Continued).

Substance.	Average Specific Gravity.	Average Weight per Cu. Ft. Lb.
Oxygen gas, to part heavier than air	.00136	.0846
Petroleum	.878	54.8
Powder	1.00	62.3
Rosin	1.1	68.6
Silver	10.5	655.0
Slate	2.8	175.0
Steel	7.85	490.0
Sulphur	2.0	125.0
Tallow	.94	58.6
lin, cast	7.35	459.0
Water, pure, rain or distilled, at 32° F., Barom. 30 in.		62.417
Water, pure, rain or distilled, at 62° F., Barom. 30 in.	1.00	62.355
Water, pure, rain or distilled, at 212° F., Barom. 30 in.		59.7
Water, sea, average	1.028	64.08
Zinc	7.00	437.5

The following table gives the specific gravities of various coals:

Name of Coal.	Sp. Gr.	Weight of a Cu. Ft. Lb.	Weight of a Cu. Yd. Tons.
Newcastle Hartley, England	1.29	80.6	.972
Wigan, 4 ft., England	1.20	75.0	.914
Portland, England	1.30	81.2	.978
Anthracite, Wales	1.39	86.9	1.047
Eglington, Scotland	1.25	78.1	.941
Anthracite, Irish	1.59	99.4	1.193
Anthracite, Pennsylvania	1.55	96.9	1.167
Bituminous, Pennsylvania	1.40	87.5	1.054
Block coal, Indiana	1.27	79.4	.956

SPECIFIC GRAVITY AND WEIGHT OF PREPARED ANTHRACITE COAL.

To Mr. Irving A. Stearns, General Superintendent of the Pennsylvania Railroad Co.'s Coal Department, we are indebted for the following summary of tests made by the mining engineers of the company.

In a series of tests to ascertain the specific gravity of the coal from different seams worked by the company, it was found that the average specific gravity was 14784, and the average weight per cubic foot was 92.50 lb. This was calculated for space filled at breaker without settling. Add 5% for packed spaces of large heaps.

WEIGHT PER CUBIC FOOT OF SUSQUEHANNA COAL CO.'S WHITE ASH ANTHRA-CITE COAL.

Size.	Size of	Mesh.	Weight per	Cu.Ft. From 1 Cu. Ft. Solid.	
	Over.	Through.	Cu. Ft. Pounds.		
Lump	4½" to 9 " 2½" to 2½" 1½" to 2½" 1½" to 1½" 1 " to 1½" 1 " to 1½" ½" to 1½" ½" to 1½"	3½" to 4½" 2½" to 2½" 1½" to 2½" 1½" to 1½" 1 " to 1½" ½" to ½" ½" to ½" ½" to ½"	57 53 52 51 51 51 50 50 50 50	1.614 1.755 1.769 1.787 1.795 1.804 1.813 1.813	

LINE SHAFTING.

Shafting is usually made cylindrically true, either by a special rolling process, when it is known as cold-rolled shafting, or it is turned up in a machine called a lathe. In the latter case, it is called bright shafting. What

inachine called a lathe. In the latter case, it is called bright shafting. What is known as black shafting is simply bar iron rolled by the ordinary process and turned where it receives the couplings, pulleys, bearings, etc.

Bright turned shafting varies in diameter by \(\frac{1}{2}\) in up to about \(3\frac{1}{2}\) in. in diameter; above this diameter the shafting varies by \(\frac{1}{2}\) in. In eactual diameter of a bright shaft is \(\frac{1}{2}\) in less than the commercial diameter, it being designated from the diameter of the ordinary round bar iron which it is turned. Thus, a length of what is called \(3''\) bright shafting is only \(2\frac{1}{2}\) in. in diameter.

Cold-rolled shafting is designated by its commercial diameter; thus, a length of what is called \(3''\) shafting is \(3\) in. in diameter.

Cold-rolled iron is considerably stronger than ordinary turned wrought iron; the increased strength being due to the process of rolling, which seems to compress the metal and so make it denser—not merely skin deep, but practically throughout the whole diameter.

practically throughout the whole diameter.

STRENGTH OF SHAFTING.

Let

D = diameter of shaft;

R = revolutions per minute; H = horsepower transmitted;

C = constant given in table.

CONSTANTS FOR LINE SHAFTING.

In the accompanying table the bearings are supposed to be spaced so

Material of Shaft.	No Pulleys Between Bearings.	Pulleys Between Bearings.	excessive bending; also, in the third vertical col- umn, an average number and weight of pulleys
Steel or cold-rolled iron	65	85	and power given off is
Wrought iron	70	95	assumed. In determining the
Cast iron	90	120	constants given in the

lowance has been made to insure the stiffness as well as strength of the shaft.
$$H = \frac{D^3 \times R}{C}. \qquad D = \sqrt[3]{\frac{C \times H}{R}}. \qquad R = \frac{C \times H}{D^3}.$$

Shafts are subject to forces that produce stresses of two kinds—transverse and torsional. When the machines to be driven are below the shaft, there is a transverse stress on the shaft, due to the weight of the shaft itself, of the pulley and tension of the belt. Sometimes the power is taken off horizontally on one side, in which case the tension of the belt produces a horizontal transverse stress, while the weight of the pulley acts with the weight of the shaft to produce a vertical transverse stress. When the machinery to be driven is placed on the floor above the shaft, the tension of the belt produces a transverse stress in opposite direction to that due to the weight of the shaft and pulley.

The torsional strength of shafts, or their resistance to breaking by twisting, is proportional to the cube of their diameter. Their stiffness or resistance to bending is proportional to the fourth power of their diameters, and inversely proportional to the cube of the lengths of their spans. No simple general formula can be given that will safely apply to engine and other shafting that is subjected to the bending stresses produced by overhung cranks, the weight of heavy flywheels, the pull of large belts, or to severe shocks produced by the intermittent action of the power or load. The calculations for such shafts should always be based on the special conditions involved.

In the following table is given the maximum distance between the bear-

In the following table is given the maximum distance between the bearings of some continuous shafts that are used for the transmission of power. Pulleys from which considerable power is to be taken should always be placed as close to a bearing as possible.

The diameters of the different lengths of shafts composing a line of shafting may be proportional to the quantity of power delivered by each respective that the statement of the shaft of the contraction of the shaft of the statement of the shaft of the s length. In this connection, the positions of the various pulleys depend the distance between the pulley and the bearing, and on the amount of rer given off by the pulleys. Suppose, for example, that a piece of shaft-

i delivers a certain amount of ver; then, it is obvious that the it will deflect or bend less if the fley transmitting that power be seed close to a hanger or bears, than if it be placed midway tween the two hangers or bears, it is impossible to give any lefor the proper distance of bears that could be used universally, as in some cases the requirements demand that the bearings e nearer together than in others, the work done by a line of shafting is distributed quite equallyong its entire length, and the power can be applied near the middle, the strength of the shaft need be only half as great as would

Diameter	Distance Between Bearings.						
of Shaft.	Feet.						
Inches.	Wrought-Iron Shaft.	Steel Shaft					
2 3	11 13	11.50					
4 5	15 15 17	13.75 15.75 18.25					
6	19	20.00					
7	21	22.25					
8	23	24.00					
9	25	26.00					

be required if the power were applied at one end of the shaft.

WEIGHT OF CASTINGS.

To Find the Approximate Weight of a Casting.—For iron, multiply the weight of the pattern by 20. Copper is 1 heavier; lead, 2 heavier; brass, 1 heavier; and zinc is 3% as heavy.

Thickness or Diameter. Inches.	Weight of a Square Foot. Pounds.	Weight of a Square Bar 1 Ft. Long. Pounds.	Weight of a Round Bar 1 Ft. Long. Pounds.	Thickness or Diameter. Inches.	Weight of a Square Foot. Pounds.	Weight of a Square Bar 1 Ft. Long. Pounds.	Weight of a Round Bar 1 Ft. Long. Pounds.
1	9.375	.195	.154	41	168.7	63.33	49.71
į	14.06	.440	.346	4	173.4	66.86	52.52
Ĭ.	18.75	.781	.610	47	178.1	70.52	55.39
i	23.44	1.221	.959	47	182.8	74.27	58.34
ž	28.12	1.758	1.381	5°	187.5	78.12	61.37
į	32.81	2.393	1.880	5 <u>+</u>	196.9	86.14	67.65
1	37.50	8.125	2.455	51	206.2	94.54	74.26
11	42.19	3.955	3.107	5 5 1 5 1 5 1	215.6	103.3	81.16
1 <u>1</u>	46.87	4.883	3.835	l 6	225.0	112.5	88.36
14	51.57	5.909	4.640	61 61 61	234.4	122.1	95.89
14	56.26	7.033	5.523	6 i	243.8	132.0	103.7
1	60.94	8.253	6.484	6	253.1	142.4	111.9
14	65.63	9.572	7.518	l 7	262.5	153.2	120.2
14	70.32	10.99	8.630	71 71	271.9	164.2	129.0
2	75.01	12.50	9.821	7 i	281.3	175.8	138.1
$2\frac{1}{8}$	79.70	14.11	11.09	l 7≩	290.7	187.7	147.4
21/4	84.40	15.83	12.43	8 81 81 81	300.0	200.1	157.0
21	89.07	17.63	13.85	81	309.4	212.7	167.0
21	93.75	19.54	15.34	8 <u>i</u>	318.8	225.8	177.3
24	98.44	21.54	16.56	l 8₹	328.2	239.3	187.9
24	103.2	23.64	18.56	9	337.4	253.1	198.8
24	107.8	25.84	20.29	91	346.8	267.4	210.0
3	112.6	28.13	22.10	9 1 9 1 9 1	356.2	282.1	221.5
31	117.3	30.52	23.97	91	365.6	297.0	233.3
31	121.8	33.01	25.93	10	375.0	312.5	245.5
3)	126.5	35.60	27.95	101	384.4	328.4	257.8
34	131.2	38.28	30.07	10i	393.7	344.5	270.6
34	135.9	41.07	32.25	101	403.1	361.2	283.7
34	140.6	43.95	34.51	11	412.5	378.2	297.0
34	145.3	46.93	36.85	111	421.9	395.5	310.6
1+1++++12 222 222 3 333 34 4+44	150.0	50.01	39.27	111	431.2	413.3	324.6
4	154.7	53.18	41.77	11‡	440.6	431.4	338.8
44	159.3	56.46	44.33	12	450.0	450.0	353.4
44	164.0	59.82	46.99	l		1	
		<u> </u>	·	<u>'</u>	·	·	<u> </u>

WEIGHTS OF SHEETS AND PLATES OF STEEL, WROUGHT IRON, COPPER, AND BRASS.

(Cambria Steel Co.)

AMERICAN, OR BROWN & SHARPE, GAUGE.

No.	Thickness.		Weight Per 8	Square Foot.	
of Gauge.	Inch.	Steel.	Iron.	Copper.	Brass
0000	.460000	18.7680	18.4000	20.8380	19.6880
000	.409642	16.7134	16.3857	18.5568	17.5327
00	.364796	14.8837	14.5918	16.5253	15.6133
0	.324861	13.2543	12.9944	14.7162	13.9041
i	.289297	11.8033	11.5719	13.1052	12.3819
3	.257627	10.5112	10.3051	11.6705	11.0264
3	.229423	9.3605	9.1769	10.3929	9.8193
4	.204307	8.3357	8.1723	9.2551	8.7443
5	.181940	7.4232	7.2776	8.2419	7.7870
6 7	.162023	6.6105	6.4809	7.3396	6.9346
7	.144285	5.8868	5.7714	6.5361	6.1754
8	.128490	5.2424	5.1396	5.8206	5.4994
9	.114423	4.6685	4.5769	5.1834	4.8973
10	.101897	4.1574	4.0759	4.6159	4.3612
11	.090742	3.7023	3.6297	4.1106	3.8838
12	.080808	3.2970	3.2323	3.6606	3.4586
13	.071962	2.9360	2.8785	3.2599	3.0800
14	.064084	2.6146	2.5634	2.9030	2.7428
15	.057068	2.3284	2.2827	2.5852	2.4425
16	.050821	2.0735	2.0328	2.3022	2.1751
17	.045257	1.8465	1.8103	2.0501	1.9370
18	.040303	1.6444	1.6121	1.8257	1.7250
19	.035890	1.4643	1.4356	1.6258	1.5361
20	.031961	1.3040	1.2784	1.4478	1.3679
21	.028462	1.1612	1.1385	1.2893	1.2182
22	.025346	1.0341	1.0138	1.1482	1.0848
23	.022572	.92094	.90288	1.0225	.96608
24	.020101	.82012	.80404	.91058	.86032
25	.017900	.73032	.71600	.81087	.76612
26	.015941	.65039	.63764	.72213	.68227
27	.014195	.57916	.56780	.64303	.60755
28 29	.012641	.51575	.50564	.57264	.54103
29	.011257	.45929	.45028	.50994	.48180
30	.010025	.40902	.40100	.45413	.42907
31	.008928	.36426	.35712	.40444	.38212
32	.007950	.32436	.31800	.36014	.34026
33	.007080	.28886	.28320	.32072	.30302
34	.006305	.25724	.25220	.28562	.26985
35	.005615	.22909	.22460	.25436	.24032
36	.005000	.20400	.20000	.22650	.21400
37	.004453	.18168	.17812	.20172	.19059
38	.003965	.16177	.15860	.17961	.16970
39 40	.003531	.14406	.14124	.15995	.15113
40	.003144	.12828	.12576	.14242	.13456

WEIGHT OF CAST-IRON PIPE PER FOOT IN FOUNDS. These weights are for plain pipe. For hautboy pipe, add 8 in. in length for each joint. For copper, add \(\frac{1}{2}\); for lead, \(\frac{2}{2}\); for welded iron, \(\frac{1}{2}\).

or cach	Joint.	1.01	сорр	ci, au	u 8,	101 10	caru, 1	, 101	M C1	ucu 1	1011, 3	18.	
Diam- eter of				Th	ickne	ss of	Pipe.	Inc	hes.				
Bore. inches.	- 1	ŧ	+	ŧ	+	ŧ	1	11	11	1}	11	1#	2
1	3.07	5.07	7.38	1	i						1		
11	3.69	6.00	8.61								1		
11	4.30	6.92	9.84					. 1					i
1	4.92	7.84	11.10	1				1		ŀ			
2	5.53	8.76	12.30	16.2									ŀ
21 21	6.15	9.69	13.50	17.7									ľ
24	6.76	10.60	14.80	19.2	24.0								i
2≩	7.37	11.50	16.00	20.8	25.9			l i					ł
3	7.98	12.50	17.20	22.3	27.7	33.4				l			
31	9.21	14.30	19.70		31.4	37.7							
4	10.30	16.10	22.20	28.5	35.1	42.0							l
4	11.70	18.00	24.60		38.8	46.3							l
5	12.90	19.80	27.10	34.6	42.5	50.6							
5	14.20	21.70	29.50	37.7	46.1	54.9		1					
6	15.40	23.50	32.00	40.8		59.2	68.9						
6 1	16.60	25.40	34.50	43.8	53.5	63.5	73.8	84.4					
7	17.80	27.20	36.90	46.9		67.8	78.7	89.4					
7∔	19.10	29.10	39.40	50.0	60.9	72.1	83.7	95.5	108				1
8	20.30	30.90	41.80	53.1	64.6	76.4		101.0	114	127			
8 84	21.50	32.80	44.30	56.1	68.3	80.7		107.0	120	134	148		
9	22.80	34.60	46.80	59.2	72.0	85.1		112.0	126	140	155		
91	24.00	36.40	49.20	62.3	75.7	89.3	103.0		132	147	163		
10	25.10	38.30	51.70	65.3	79.4		108.0		138	164	170	202	
11	27.60	42.00	56.60	71.5	86.7	102.0	118.0	134.0	151	168	185	220	
12	30.00	45.70	61.50				128.0		163	181	199	237	275
13	32.50	49.40	66.40	83.8			138.0		175	195	214	254	294
14	35.00	53.10	71.40				148.0		188	208	229	271	314
15	37.40	56.70	76.30	96.1	116.0	137.0	158.0	179.0	200	222	244	289	334
16	39.10	60.40	81.20	102.0	124.0	145.0	167.0	190.0	212	235	258	306	353
17	42.30	64.10	86.10	108.0	131.0	154.0	177.0	201.0	225	249	273	323	373
18	44.80	67.80					187.0		237	262	288	340	393
19	47.30	71.50					197.0		249	276	303	357	412
20 21 22 23	49.70	75.20	101.00						261	289	317	375	432
21	52.20		106.00						274	303	332	392	452
22	54.60		111.00						286	316	347	409	471
23	57.10		116.00						298	330	362	426	491
24 25	59.60	89.90	121.00	152.0	183.0	214.0	246.0	278.0	311	343	375	444	511
25	62.00		126.00						323	357	391	461	531
26 27	64.50		131.00						335	370	406	478	550
27		101.00							348	384	421	495	570
28		105.00							360	397	436	512	590
28 29		109.00							372	411	450	530	609
30		112.00							384	424	465	547	629
				,	,,,	0.0					,		

DIAMETER AND NUMBER OF WOOD SCREWS.

Formulas for Wood Screws.	No.	Diameter.	No.	Diameter.	No.	Diameter.
N = number	0	.056	11	.201	22	.347
D = diameter	1	.069	12	.215	23	.361
$D = (N \times .01325) + .056$	2	.082	13	.228	24	.374
$N = \frac{D056}{}$	3	.096	14	.241	25	.387
.01325	4	.109	15	.255	26	.401
.01020	5	.122	16	.268	27	.414
	6	.135	17	.281	28	.427
	7	.149	18	.293	29	.440
	8	.162	19	.308	30	.453
	9	.175	20	.321	1 1	
	10	.188	21	.334	, 1	

WEIGHT OF WROUGHT IRON.

The following table is for wrought iron. Multiply by .95 for weight of cast iron; by 1.02 for steel; by 1.16 for copper; by 1.09 for brass; by 1.48 for lead.

	of a Square Foot.	Weight of a Square Bar 1 Ft. Long.	Weight of a Round Bar 1 Ft. Long.	or	of a Square Foot.	Weight of a Square Bar 1 Ft. Long.	Weight of a Round Bar 1 Ft. Long.
Inches.	Pounds.	Pounds.	Pounds.	Inches.	Pounds.	Pounds.	Pounds.
1	5.052	.0526	.0414	41	176.8	64.47	50.63
Ţ	10.10	.2105	.1653	41	181.9	68.20	53.57
i	15.16	.4736	.3720	4	186.9	72.05	56.59
I	20.21	.8420	.6613	41	192.0	75.99	59.69
i	25.26	1,316	1.033	4:	197.0	80.05	62.87
1	30.31	1.895	1.488	5 5 1	202.1	84.20	66.13
į	35.37	2.579	2.025	5 1	212.2	92.83	72.91
1	40.42	3.368	2.645	l 5≩	222.3	101.9	80.02
1	45.47	4.263	3.348	5#	232.4	111.4	87.46
1 1	50.52	5.263	4.133	6	242.5	121.3	95.23
1 i	55.57	6.368	5.001	61	252.6	131.6	103.3
11	60.63	7.578	5.952	61	262.7	142.3	111.8
1	65.68	8.893	6.985	6	272.8	153.5	120.5
1# 1#	70.73	10.31	8.101	7	282.9	165.0	129.6
17	75.78	11.84	9.300	7 1	293.0	177.0	139.0
2	80.83	13.47	10.58	71	303.1	189.5	148.8
2 21 21 21 21 21 21 21 21	85.89	15.21	11.95	74	313.2	202.3	158.9
2 I	90.94	17.05	13.39	8 8 8 8	323.3	215.6	169.3
2	95.99	19.00	14.92	8‡	333.4	229.3	180.1
21	101.0	21.05	16.53	84	343.5	243.4	191.1
2	106.1	23.21	18.23	l 8≇	353.6	247.9	202.5
2₽	111.2	25.47	20.01	9	363.8	272.8	214.3
2‡	116.2	27.84	21.87	91	373.9	288.2	226.3
3	121.3	30.31	23.81	9 <u>i</u>	384.0	304.0	238.7
3 1	126.3	32.89	25.83	9‡	394.1	320.2	251.5
31	131.4	35.57	27.94	10	404.2	336.8	264.5
34	136.4	38.37	30.13	101	414.3	353.9	277.9
31	141.5	41.26	32.41	10 <u>i</u>	424.4	371.3	291.6
31	146.5	44.26	34.76	10≩	434.5	389,2	305.7
3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3	151.6	47.37	37.20	11	444.6	407.5	320.1
37	156.6	50.57	39.72	11 1	454.7	426.3	334.8
4	161.7	53.89	42.33	114	464.8	445.4	349.8
41 41	166.7	57.31	45.01	11‡	474.9	465.0	365.2
41	171.8	60.84	47.78	12	485.0	485.0	380.9

SPIKES AND NAILS.

	Stan	dard Ste	eel-Wire	Nails.		Steel-Wire Spikes. Common Iron Nails.				W-21-	
01	Length.	ength. Common. Finis		shing.	Sieci	wite of	Common from Name.				
Sizes.	In.	Diam. In.	No. per Lb.	Diam. In.	No. per Lb.	Length. In.	Diam. In.	No. per Lb.	Size.	Length.	No. per Lb.
2d	1	.0524	1,060	.0453	1,558	3	.1620	41	2d	1	800
3d	11	.0588	640	.0508	913	31	.1819	30	3d	11	400
4d	11	.0720	380	.0508	761	4	.2043	23	4d	īį	300
5d	17	.0764	275	.0571	500	41	.2294	17	5d	1	200
6d	2	.0808	210	.0641	350	5	.2576	13	6d	2	150
7d	21	.0858	160	.0641	315	51	.2893	11	7d	21	120
8d	2	.0935	115	.0720	214	6	.2893	10	8d.	2	85
9d	2#	.0963	93	.0720	195	61	.2249	71	9d	22	75
10 d	3	.1082	77	.0808	137	7	.2249	7	10d	3	60
12d	31	.1144	60	.0808	127	8	.3648	5	12d	31	50
16d	3	.1285	48	.0907	90	9	.3648	41	16d	3	40
20d		.1620	31	.1019	62			. 1	20d	4	20
30d	4	.1819	22						30d	41	16
40d	5	.2043	17						40d	5	14
50d	51	.2294	13					'	50d	51	11
60d	16	.2576	11						COA	6	8

WEIGHT, IN POUNDS, OF 1 LINEAL FOOT OF WROUGHT IRON-FLAT. Multiply by .95 for weight of cast iron; by 1.02 for weight of steel; by 1.16 for copper; by 1.09 for brass; by 1.48 for lead.

at copper, by 1.00 for brand, by 1.10 for read.										
Size. Inches.	Weight. Pounds.	Size. Inches.	Weight. Pounds.	Size. Inches.	Weight. Pounds.					
1 14 1 2 2 2 2 2 3 3 3 4 4 4 4 4 4 5 5 5 5 5 6 6 1 1 1 1 1 1 2 2 2 2 2 3 3 3 3 4 4 4 4 4 4 5 5 5 5 6 6 1 1 1 1 1 1 2 2 2 2 2 3 3 3 3 4 4 4 4 4 4 5 5 5 6 6 6 1 1 1 1 1 1 2 2 2 2 2 3 3 3 3 3 4 4 4 4 4 4 5 5 5 6 6 6 6 6 6 6 6 6 6 6	0.85 1.06 1.27 1.48 1.69 1.90 2.11 2.32 2.53 2.75 2.96 3.17 3.38 3.59 4.01 4.22 4.44 4.65 4.86 5.07 1.27 1.58 1.90 2.253 2.85 3.17 3.49 3.80 4.12 4.44 4.75 5.07 5.39 5.70 6.02 6.33	54××× *** *** *** *** *** *** ***	6.65 6.97 7.29 7.60 1.69 2.11 2.53 2.96 3.88 3.80 4.22 4.65 5.07 5.49 5.92 6.36 6.76 7.18 8.03 8.45 8.87 9.70 1.14 2.11 2.64 3.17 3.70 4.22 4.75 5.81 6.87 7.39 7.92	4 44 44 5 5 5 5 6 11 1 1 1 2 2 2 2 2 3 3 3 5 4 4 4 4 5 5 5 5 6 6 7	8.45 8.98 9.51 10.03 10.56 11.09 11.62 12.15 12.67 2.53 3.17 3.80 4.44 5.07 5.70 6.33 6.97 7.60 8.24 8.87 9.51 10.14 12.67 13.31 12.67 13.31 12.67 13.31 14.57 15.21 5.70 6.76 10.14 11.57 15.21 5.70 6.76 10.14 11.57 11.57 15.21					

STRENGTH OF	METALS I	N POUNDS	PER SQUA	RE INCH.	
Material.	Ultimate Tensile.	Ultimate Compres- sion.		Modulus of Rupture.	Modulus of Elasticity. Millions.
Wrought iron Shape iron	50,000 48,000 60,000	44,000	44,000	48,000	27 26
Structural steel	65,000	52,000	52,000	60,000	29
Cast iron	18,000	81,000	25,000	45,000	12
Steel, castings	70,000	70,000	60,000	70,000	30
BTBBS, Cast	24,000	*30,000	36,000	20,000	9
pronze, phosphor	50,000	,		ì '	14
Bronze, aluminum	75,000	120,000			
Aluminum, commercial	15,000	12,000	12,000		11

^{*}Unit stress producing 10% reduction in original length.

WEIGHT OF WROUGHT-IRON BOLTHEADS, NUTS, AND WASHERS.

Diameter of Bolt. Inches.	Hexagon Heads and Nuts. Per Pair.	Square Heads and Nuts. Per Pair.	Round Washers Per Pair.
1 4 2 1 6 1	20 to a lb. 10 to a lb. 5 to a lb.	16 to a lb. 81 to a lb. 41 to a lb.	20 to a lb. 10 to a lb. 5 to a lb.
1 d d d d d d d d d d d d d d d d d d d	2\(\) to a lb. 2 to a lb. 0.77 lb. 1.25 lb.	2½ to a lb. 0.56 lb. 0.88 lb. 1.31 lb.	3 to a lb. 0.63 lb. 0.77 lb. 1.25 lb.
11 14 13 13	1.75 lb. 2.13 lb. 3.00 lb. 3.75 lb.	2.10 lb. 2.56 lb. 3.60 lb. 4.42 lb.	1.75 lb. 2.25 lb. 8.25 lb. 4.25 lb.
15 13 17 17 2	4.75 lb. 5.75 lb. 7.27 lb. 8.75 lb.	5.70 lb. 7.00 lb. 8.72 lb. 10.50 lb.	5.25 lb. 6.50 lb. 8.00 lb. 9.60 lb.

WEIGHT OF 100 BOLTS WITH SQUARE HEADS AND NUTS. (The Carnegie Steel Co., Limited.)

Length				Diam	eter of 1	Bolts.			
Under Head to Point.	‡" Ľb.	Ь. Цр.	3'' Lb.	£Ъ.	1" Lb.	#" Lb.	3"' Lb.	<i>I''</i> Lb.	1" Lb
11 12 2 22 24 24 4 5 5 6 6 7 7 8 9 10 11 12 13 14 15 16 17 18 19 20	4.0 4.4 4.8 5.5 5.8 6.3 7.0 7.8 8.5 9.3 10.0	7.0 7.5 8.0 8.5 9.0 9.5 10.0 11.0 13.0 14.0 15.0	10.5 11.3 12.0 13.5 14.3 15.0 16.5 18.0 22.5 24.0 25.5 27.0 28.5 30.0	15.2 13.3 17.4 18.5 19.6 20.7 21.8 24.0 26.2 28.4 30.6 37.2 39.4 41.6 48.2 45.2 50.4 52.6	22.5 23.8 25.2 26.5 27.8 29.1 30.5 33.1 35.8 4 41.1 49.0 51.7 54.6 64.9 70.5 80.8 91.4 96.7 102.0 107.3 112.6 117.9 123.2	39.5 41.6 43.8 45.8 45.8 45.0 50.1 52.3 56.5 65.0 69.3 73.5 77.8 82.0 90.5 94.8 103.3 111.8 120.3 128.8 137.3 145.8 171.0 171.	63.0 66.0 69.0 72.0 75.0 75.0 87.0 93.1 105.2 111.3 117.3 123.4 135.0 141.5 153.6 165.7 177.8 189.9 202.0 214.1 226.2 238.3 250.4 262.6 274.7 286.8	109.0 113.3 117.5 121.8 126.0 134.3 142.5 151.0 176.6 185.0 193.7 202.0 221.8 224.8 224.8 224.9 278.9 330.1 347.1 364.2 381.2 381.2	163 169 174 180 185 196 207 218 229 240 251 262 273 284 295 317 339 360 382 404 426 426 436 451 451 451 451 451 451 451 451 451 451
Per Inch Addit'al.	1.4	2.1	3.1	4.2	5.5	8.5	12.3	16.7	21.8

IRON REQUIRED FOR ONE MILE OF TRACK.

TONS OF IRON.

Rule.—To find the number of tons of rails to the mile, divide the weight per yard by 7, and multiply by 11. Thus, for 58-pound rail, divide 56 by 7 equal 8, multiplied by 11 equal 88 tons, for 1 mile of single track.

Weight of Rail per Yard	Tons I	oer Mile.	Weight of	Tons per Mile.		
Rail per Yard. Pounds.	Tons.	Pounds.	Rail per Yard: Pounds.	Tons.	Pounds	
12	18	1,920	45	70	1,600	
14 16	22 25 28	320	48 50	75 78	960 1,280	
18	28	640	52	81	1,600	
	31	960	56	88	1,000	
20 22 25 26 27 28	34	1,280	57	89	1,280	
25	39	640	60	94	640	
26	40 42 44 47 51 55 62	1,920	62	97	960	
27	42	960	64	100	1,280	
28	44	1	65	102	320	
30	47	320	68	106	1,920	
30 33	51	1,920	70	110		
35	55	1 '	72	113	320	
40	62	1,920	76	119	960	

NUMBER OF RAILS, SPLICES, AND BOLTS PER MILE OF TRACK.

Length of Rail. Feet.	No. of Rails per Mile.	No. of Splices.	No. of Bolts, 4 to Each Joint.	No. of Bolts, 6 to Each Joint.
18	584	1,168	2,336	3,504
20	528		2,112	3,168
21 22	503 480	1,056 1,006 960	2,112 2,012 1,920	3,018 2,880
24	440	880	1,760	2,640
25	422	844	1,688	2,532
26	406	812	1,624	2,436
27	391	782	1,564	2,346
28	377	754	1,508	2,262
30	352	704	1,408	2,112

RAILROAD SPIKES PER MILE OF TRACK.

Size Measured Under Head.	Average No. per Keg	Ties 2 Ft. Betw 4 Spikes		Rails Used. Pounds per
51 × 18 5 × 18 5 × 18 5 × 18	of 200 Lb.	Pounds.	Kegs.	Yard.
5 1 × ♣	375	5,870	29}	45 to 70
	400	5,170	26	40 to 56
	450	4,660	231	35 to 40
41×11	530	3,960	20	28 to 35
4 × ±	600	3,520	178	24 to 35
$\begin{array}{c} 44 \times \frac{7}{48} \\ 4 \times \frac{7}{48} \end{array}$	680 720	3,110 2,910	15 14 2	} 20 to 30
31 × 7	900 1,000	2,350 2,090	11 101	} 16 to 25
34 × 4 3 × 4	1,190 1,240	1,780 1,710	9 ⁻	} 16 to 20
24 🛇	1,342	1,575	77	12 to 16

WIRE ROPES.

Wire ropes for mine use are made of either iron or steel, and are generally round. Flat wire ropes are sometimes used, but the round rope is the favorite for many reasons, and is generally used in American practice excepting in some of the deep metal mines having small compartment shafts.

Taper ropes are sometimes used, the idea being to produce a rope of uniform strength, that is, to have it less strong and of less diameter at the cage end, where the load is least, and greater in strength and diameter at the drum end, where the load is greatest. The theory is correct, and some weight of rope is saved; but practically there is not much advantage, and it is doubtful whether taper ropes will ever be generally used. The longestablished conviction that the best of all ropes for colliery use is a round one made of steel or iron has never been overcome and probably never will be.

Steel ropes are in most respects superior to iron ropes, and are therefore gaining in favor every year. The principal advantage of a steel rope is that it has a greater strength than an iron rope of equal diameter; consequently, it can be made lighter and can pass around pulleys and drums with less

injury than an iron rope of equal strength.

In fastening a rope to a drum there is often a grievous error made. who will not think of passing a rope around a pulley of too small diameter

will insert it in the drum rim in such a way as to make a very sharp curve, and make a weak point in the rope that would not otherwise exist. In the accompanying cut (a) shows the right and (b) the wrong way of passing the rope through the drum rim. The securing of the rope to the drum or



the drum shaft by several coils around each is unnecessary. With one coil around either the drum or the shaft, a pull of 1 lb. will resist a weight of 9 lb.; if two coils, a pull of 1 lb. will resist 9×9 , or 81 lb.; if three coils, $9 \times 9 \times 9$, or 729 lb.; and so on, multiplying the former result by 9 for each

additional coil.

No rope should be subjected to a load greater than the safe working strain. There is, of course, in all cases, a wide margin between the breaking strain and the working load, and on this account it is supposed that no risk is run by putting on a load considerably in excess of the maker's safe working strain. This is a mistake; and it is false economy. A rope overloaded is unduly strained, and, although showing no defect at the moment, it will some day give way without warning. Drums and rope pulleys should have as great diameters as the engines will allow. Ropes should be regularly and properly greased. This can best be done with brushes, but brush greasing takes considerable time. While it pays in the long run, it is not always convenient to use brushes. A fairly good and cheap arrangement for greasing ropes is to make a wooden trough, wide at top, and small enough at bottom to fit loosely around the rope. Make a mixture of 1 barrel of coal tar or pitch tar to 1 bushel of fresh slaked lime, and boil it well. Then fill the trough with this mixture and run the rope slowly through it.

A rope should not be changed from a large drum to a small one, for it will not work so well, neither will it last as long. This is also true, but in a lesser degree, of ropes changed from a small drum to a large one. After having been used for some time on a drum, the rope adapts itself to that diameter and resents a change. Rope sheaves should be made to fit the rope, and should be filled in with well-seasoned blocks of oak or other hard wood, set on end. This will save the rope and increase adhesion.

Where great flexibility is required, such as in hoisting ropes, the strands are usually made up of 19 wires each, while haulage ropes have but 7 wires to the strand; yet, both kinds have 6 strands. A hemp core is generally used, and in some cases a core is also placed in each strand, to further increase the flexibility of the rope.

The lay of the rope is the twist or pitch of the wires in the strand, or of

the strands in the rope. As the lay of the wires is less than that of the strands, each wire is exposed to external wear for short distances at intervals along the rope. In the ordinary lay, Fig. (a), the wires are twisted in the opposite direction to the strands. This method prevents the rope from untwisting when in use, and the wires from unraveling when they are worn through or broken at the surface. In the Lang lay, Fig. (b), the wires are twisted in the same direction as the strands, thus giving each wire a greater wearing surface, while the rope is smoother and will wear longer. After the wires begin to break, unraveling becomes troublesome, and it is more difficult to splice a Lang lay rope than an ordinary lay one. Hoisting ropes, especially those used to raise and lower men, should not be spliced The locked wire rope, a cross-section of which is shown in Fig. (c), consists of wires of special cross-section formed in concentric layers. The lay of the inner wires is opposite to that of the outer ones, and somewhat longer. This prevents untwisting, and brings the greater stress upon the outside







layer, which is supposed to give way first. The inside layer, although inaccessible, and therefore cannot be inspected or oiled, can be relied upon until the external portion of the rope wears out. This form of rope has a smooth cylindrical surface, but it is not so flexible as the other forms, and is most suitable for haulage purposes or bucket transportation. The life of a steel rope depends largely on the conditions to which it is subjected, and the care it receives. At some mines the ropes must be changed every six months, while at others the ropes last for one year and longer. Where the rope enters the socket by which it is attached to the cage is perhaps the place where signs of weakness will first appear. This point should be frequently inspected, and a new connection made every two or three months by cutting a few feet off the end and paying it out from the drum end.

WEIGHTS AND STRENGTHS OF WIRE ROPES.

FLAT ROPES.

(Trenton Iron Co., Trenton, N. J.)

Size. Inches.	Approximate Weight per Foot.		ng Stress. ite.) Pounds.
	Pounds.	· Iron.	Cast Steel.
2 × † 24 × † 34 × † 4 × † 4 5 6 × †	1.35	20,000	40,000
	1.70	25,000	50,000
	2.05	30,000	60,000
	2.40	35,000	70,000
	2.75	40,000	80,000
	3.45	50,000	100,000
	4.15	60,000	120,000
3 × ± ± 4 × ± ± 5 × ± ± 7 × ± ± 78 × ± ± 6 7 × ± 5 7 × ± ± 6 7 × ± 5 7 × ± ± 6 7 × ± 5 7 ×	2.40	37,500	75,000
	2.85	43,750	87,500
	3.30	50,000	100,000
	4.20	62,500	125,000
	5.10	75,000	150,000
	6.00	87,500	175,000
	6.90	100,000	200,000

For safe working load allow from one-fifth to one-seventh of the breaking stress.

COMPOSED OF 6 STRANDS AND A HEMP CENTER, 19 WIRES TO THE STRAND. (John A. Roebling's Sons Co., Trenton, N. J.)

SWEDISH IRON.

Trade Number.	Diameter. Inches.	Approximate Circumfer- ence. Inches.	Weight per Foot. Pounds.	Approximate Breaking Strain. Tons of 2,000 Lb.	Allowable Working Strain. Tons of 2,000 Lb.	Minimum Size of Drum or Sheave. Feet.
1 2 3 4 5	$\begin{array}{c} 2\frac{1}{4} \\ 2 \\ 1\frac{3}{4} \\ 1\frac{5}{8} \\ 1\frac{1}{2} \end{array}$	$7\frac{1}{8}$ $6\frac{1}{4}$ $5\frac{1}{9}$ 5 $4\frac{3}{4}$	8.00 6.30 4.85 4.15 3.55	78.0 62.0 48.0 42.0 36.0	15.60 12.40 9.60 8.40 7.20	13 12 10 8 ¹ / ₂ 7 ¹ / ₂
$ \begin{array}{c} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ \hline 5^{\frac{1}{4}} \\ 6 \\ 7 \\ 8 \\ 9 \end{array} $	13 14 14 18 1	$\begin{array}{c} 4\frac{1}{4} \\ 4 \\ 3\frac{1}{2} \\ 3 \\ 2\frac{3}{4} \end{array}$	3.00 2.45 2.00 1.58 1.20	31.0 25.0 21.0 17.0 13.0	6.20 5.00 4.20 3.40 2.60	$\begin{array}{c} 7 \\ 6\frac{1}{9} \\ 6 \\ 5\frac{1}{4} \\ 4\frac{1}{9} \end{array}$
10 $10\frac{1}{4}$ $10\frac{1}{2}$ $10\frac{3}{4}$ $10a$	128 114 16 17 18 24 48 0 16 2 7 7 18 28 6 6 6 7 4 4	$ \begin{array}{c} 2\frac{1}{4} \\ 2 \\ 1\frac{3}{4} \\ 1\frac{1}{2} \\ 1\frac{1}{4} \end{array} $.89 .62 .50 .39	9.7 6.8 5.5 4.4 3.4	1.94 1.36 1.10 .88 .68	$\begin{array}{c} 4 \\ 3\frac{1}{2} \\ 2\frac{3}{4} \\ 2\frac{1}{4} \\ 2 \end{array}$
$\begin{array}{c} 10b \\ 10c \\ 10d \end{array}$	5 16 4	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	.22 .15 .10	2.5 1.7 1.2	.50 .34 .24	1½ 1 3

CAST STEEL.

1 2 3 4 5	2 ¹ / ₄ 2 1 ³ / ₈ 1 ¹ / ₈	7 1 6 4 5 1 5 5 4 5 4 5 4 5 4 5 5 6 5 6 6 6 6 6 6 6	8.00 6.30 4.85 4.15 3.55	156.0 124.0 96.0 84.0 72.0	31.20 24.80 19.20 16.80 14.40	81 8 71 61 51
5½ 6 7 8 9	1 ½ 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	4 ¹ / ₄ 4 3 ¹ / ₉ 3 2 ² / ₄	3.00 · 2.45 2.00 1.58 1.20	62.0 50.0 42.0 34.0 26.0	12.40 10.00 8.40 6.80 5.20	5 4 4 4 3 4
10 $10\frac{1}{4}$ $10\frac{1}{2}$ $10\frac{3}{4}$ $10a$	3 4 5 8 9 16 12 7	$\begin{array}{c} 2\frac{1}{4} \\ 2 \\ 1\frac{3}{4} \\ 1\frac{1}{9} \\ 1\frac{1}{4} \end{array}$.89 .62 .50 .39	19.4 13.6 11.0 8.8 6.8	3.88 2.72 2.20 1.76 1.36	3 21 11 11 11
$10b \\ 10c \\ 10d$	3 8 5 16 14	1 to	.22 .15 .10	5.0 3.4 2.4	1.00 .68 .48	1

PLOW-STEEL ROPE.

Wire ropes of very high tensile strength, which are ordinarily called "plow-steel ropes," are made of a high grade of crucible steel, which, when put in the form of wire, will bear a stress of from 100 to 150 tons per square inch. Where it is necessary to use very long or very heavy ropes, a reduction of the dead weight of ropes becomes a matter of serious consideration. It is advisable to reduce all bends to a minimum, and to use somewhat larger drums or sheaves than are suitable for an ordinary crucible rope having a strength of 60 to 80 tons per square inch.

PLOW-STEEL ROPE-WITH 6 STRANDS AND A HEMP CENTER, 19 WIRES TO THE STRAND.

			THE STRAN		_	
Trade Number.	Diameter. Inches.	Approximate Circumfer- ence. Inches.	Weight per Foot. Pounds.	Approximate Breaking Strain. Tons of 2,000 Lb.	Allowable Working Strain. Tons of 2,000 Lb.	Minimum Size of Drum or Sheave. Feet.
1 2 3	21 21 21 21 2 11	8 7 7 7 7 7 7 7 5 6 5 5 5 6 5 5 6 5 6 5 6	11.95 9.85 8.00 6.30 4.85	305.00 254.00 208.00 165.00 128.00	61.00 50.80 41.60 33.00 25.60	11 10 9 8 7
4 5 5 4 6 7	15 15 15 15 14 14	5 4 1 41 4 31	4.15 3.55 3.00 2.45 2.00	111.00 96.00 82.00 67.00 56.00	22.20 19.20 16.40 13.40 11.20	6 51 51 5 41
8 9 10 10 10 10	1 1 1 1 1 1 1 1	3 21 21 2 11	1.58 1.20 .89 .62 .50	44.00 34.00 25.00 18.00 14.50	8.80 6.80 5.00 3.60 2.90	41 31 31 3 21
10 1 10a 10b 10c 10d	1 17 18 8 5 16	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	.39 .30 .22 .15	11.40 8.85 6.55 4.50 3.00	2.28 1.77 1.31 .90 .60	2 11 1 1
	PLOW-STE	EL ROPE—	With 7 Wi	RES TO TH	E STRAND.	
11 12 13 14 15	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	41 41 4 31 3	3.55 3.00 2.45 2.00 1.58	91.00 78.00 64.00 53.00 42.00	18.20 15.60 12.80 10.60 8.40	81 8 8 7 1 6 1 4 5
16 17 18 19 20	7	21 21 21 21 21 2	1.20 .89 .75 .62 .50	32.00 24.00 21.00 17.00 14.00	6.40 4.80 4.20 3.40 2.80	5 4 3 3 2
21 22 23 24 25	1 7 7 8 8 8 1 8 8 2 2 8 2 2	1 t t t t t t t t t t t t t t t t t t t	.39 .30 .22 .15 .125	11.00 8.55 6.35 4.35 3.65	2.20 1.71 1.27 .87 .73	2½ 2 1½ 1¼ 1

TRANSMISSION OR HAULAGE ROPE.

COMPOSED OF 6 STRANDS AND A HEMP CENTER, 7 WIRES TO THE STRAND.

SWEDISH IRON.

Trade Number.	Diameter. Inches.	Approximate Circumfer- ence. Inches.	Weight per Foot. Pounds.	Approximate Breaking Strain. Tons of 2,000 Lb.	Allowable Working Strain. Tons of 2,000 Lb.	Minimum Size of Drum or Sheave. Feet.
11 12 13 14 15	$1\frac{1}{9}$ $1\frac{3}{8}$ $1\frac{1}{4}$ $1\frac{1}{8}$	$\begin{array}{c} 4\frac{3}{4} \\ 4\frac{1}{4} \\ 4 \\ 3\frac{1}{2} \\ 3 \end{array}$	3.550 3.000 2.450 2.000 1.580	34.00 29.00 24.00 20.00 16.00	6.80 5.80 4.80 4.00 3.20	13 12 10 ³ / ₄ 9 ¹ / ₂ 8 ¹ / ₂
16 17 18 19 20	7 8 3 4 1 1 6 6 8 9 1 6	$\begin{array}{c} 2\frac{3}{4} \\ 2\frac{1}{4} \\ 2\frac{1}{8} \\ 2 \\ 1\frac{3}{4} \end{array}$	1.200 .890 .750 .620 .500	12.00 9.30 7.90 6.60 5.30	2.40 1.86 1.58 1.32 1.06	$\begin{array}{c} 7\frac{1}{2} \\ 6\frac{3}{4} \\ 6 \\ 5\frac{1}{4} \\ 4\frac{1}{2} \end{array}$
21 22 23 24 25	7 16 2 8 6 15 16 9 32	$\begin{array}{c} 1\frac{1}{2} \\ 1\frac{1}{4} \\ 1\frac{1}{8} \\ 1 \\ \frac{7}{8} \end{array}$.390 .300 .220 .150 .125	4.20 3.30 2.40 1.70 1.40	.84 .66 .48 .34 .28	4 3½ 2¾ 2½ 2½ 2½ 2½

CAST STEEL.

						
11	11	42	3.55	68.00	13.60	81
12	i îi	41	3.00	58.00	11.60	8 1 8
13	il	4	2.45	48.00	9.60	71
14	ii	31	2.00	40.00	8.00	is
15	i°	3	1.58	32.00	6.40	7 1 61 51
16		23	1.20	24.00	4.80	5
17	1	$2\frac{1}{4}$.89	18.60	3.72	
18	1 5	$2\frac{7}{6}$.75	15.80	3.16	44
	18	28				*
19	į	2	.62	13.20	2.64	3 <u>1</u> 3
20	18	17	.50	10.60	2.12	
21	1	14	.39	8.40	1.68	2‡ 2‡ 2
22	J.	11	.30	6.60	1.32	21
23	100	l îi	.22	4.80	.96	2
24		i°	.15	3.40	.68	Ĩ#
25	16	-,	.125	2.80	.56	1
20	37	T	.120	2.00	.50	T.8.

The rope usually employed for transmission of power is a seven-wire iron rope. Ropes of twelve and also of nineteen wires to the strand are frequently substituted, where it is impracticable to use the larger sheaves which seven wire ropes require. The driving sheaves should always be lined with some flexible material, such as a packing of rubber and leather.

The shortest practicable span is found by experience to be about 50 feet. The following table gives the proper deflections at center of span to secure the most economical results:

TABLE OF DEFLECTIONS.

Span in feet	50	100	150	200	250	300	350	400	450
Deflection in feet	0.17	0.69	1.56	2.78	4.34	6.25	8.52	11.12	14.07

It is frequently convenient to use sheaves of different sizes, in order to obtain the requisite speed in the driven mechanism. In such cases the power transmitted will be the same as if both were of the diameter of the caller sheave.

STRESS IN HOISTING ROPES ON INCLINED PLANES OF VARIOUS DEGREES.

(From "Wire-Rope Transportation," published by Trenton Iron Co.)

The following table is based upon an allowance of 40 lb. per ton for rolling friction, but there will be an additional stress due to the weight of the rope and inclination of the plane.

Rise per 100 Ft. Horizontal. Ft.	Angle of Inclination.	Stress in Lb. per Ton of 2,000 Lb.	Rise per 100 Ft. Horizontal. Ft.	Angle of Inclination.	Stress in Lb. per Ton of 2,000 Lb.
5	2° 52′	140	105	46° 24′	1.484
10	5º 43'	240	110	470 44'	1.516
10 15	8º 32'	336	115	490 007	1,535
20	110 10	432	120	50° 12′	1.573
25	140 03'	527	125	51° 21′	1.597
25 30	160 42'	613	130	52° 26′	1.620
35	190 18'	700	135	530 297	1,642
40	210 49	782	140	54° 28′	1.663
45	240 14'	860	145	55° 25′	1.682
50	260 34'	933	150	56° 19′	1,699
55	28° 49′	1,003	155	57° 11′	1,715
60	30° 58′	1,067	160	58° 00′	1,730
65	330 02'	1,128	165	58° 47′	1,744
70	35° 00′	1,185	170	59° 33′	1,758
75	36° 53′	1,238	175	60° 16′	1,771
80	38° 40′	1,287	180	60° 57′	1,782
85	40° 22′	1,332	185	61° 37′	1,794
90	42° 00′	1,375	190	62° 15′	1,804
95	43° 32′	1,415	195	62° 52′	1,813
100	45° 00′	1,450	200	63° 27′	1,822

RELATIVE EFFECTS OF VARIOUS SIZED SHEAVES OR DRUMS ON THE LIFE OF WIRE ROPES.

Mine officials and other users of wire ropes have often felt the want of a table or set of tables that would enable them to determine at a glance what effect the use of various sized sheaves would have on various sized ropes. The following tables have been specially prepared for the Coal and Metal Miner's Pocketbook by Mr. Thomas E. Hughes, of Pittsburg, Pa.

CAST-STEEL ROPES FOR INCLINES.

MADE OF 6 STRANDS OF 7 WIRES EACH, LAID AROUND A HEMP CORE.

Diameter	Diameters of Sheaves or Drums in Feet, Showing Percentages										
of	of Life for Various Diameters.										
Rope. Inches.	100%	90%	. 80%	75%	60%	50%	25%				
1 ½	16.00	14.00	12.00	11.00	9.00	7.00	4.75				
1 ¾	14.00	12.00	10.00	8.50	7.00	6.00	4.50				
1 ¼	12.00	10.00	8.00	7.25	6.00	5.50	4.25				
11/4	, 10.00	8.50	7.75	7.00	6.00	5.00	4.00				
11/4	8.50	7.75	6.75	6.00	5.00	4.50	3.75				
1	7.75	7.00	6.25	5.75	4.50	3.75	3.25				
#	7.00	6.25	5.50	5.00	4.25	3.50	2.75				
	6.00	5.25	4.50	4.00	3.25	3.00	2.50				
	5.00	4.50	4.00	3.50	2.75	2.25	1.75				

Note.—We do not publish a table of iron ropes for inclines, as the use of iron ropes for this purpose has been generally abandoned, steel ropes being far more satisfactory and economical.

CAST-STEEL HOISTING ROPES.

MADE OF 6 STRANDS OF 19 WIRES EACH, LAID AROUND A HEMP CORE.

Diamete					ng Perce	ntages
100%	90%	80%	75%	60%	50%	25%
14.00 12.00	12.00 10.00	10.00 8.00	8.50 7.00	7.00 6.00	6.00 5.25	4.50 4.25
10.00 9.00	8.50 7.50	7.50 6.50	6.75 5.50	5.50 5.00	5.00 4.50	4.00 3.75
8.00 7.50 5.50	7.00 6.75 4.50	6.00 5.75 4.00	5.50 5.00 3.75	4.50 4.25 3.25	4.00 3.50 3.00	3.50 3.00 2.25
4.50 4.00 3.00	4.00 3.00	3.75 3.00	3.25 2.75 2.00	3.00 2.25	2.50 2.00 1.50	2.00 1.50
	14.00 12.00 10.00 9.00 8.00 7.50 5.50 4.50	0f 100% 90% 14.00 12.00 12.00 10.00 10.00 8.50 8.00 7.50 8.00 7.50 6.75 5.50 4.50 4.50 4.00 4.00 3.00	of Life for V 100% 90% 80% 14.00 12.00 10.00 12.00 10.00 8.00 10.00 8.50 7.50 9.00 7.50 6.50 8.00 7.00 6.00 7.50 6.75 5.75 5.50 4.50 4.00 4.50 4.00 3.75 4.00 3.00 3.00	of Life for Various Dis 100% 90% 80% 75% 14.00 12.00 10.00 8.50 12.00 10.00 8.00 7.00 10.00 8.50 7.50 6.50 9.00 7.50 6.50 5.50 8.00 7.00 6.00 5.50 7.50 6.75 5.75 5.00 5.50 4.50 4.00 3.75 4.50 4.00 3.75 3.25 4.00 3.00 2.75	of Life for Various Diameters. 100% 90% 80% 75% 60% 14.00 12.00 10.00 8.50 7.00 12.00 10.00 8.00 7.00 6.00 10.00 8.50 7.50 6.75 5.50 9.00 7.50 6.50 5.50 5.50 8.00 7.00 6.00 5.50 4.50 7.50 6.75 5.75 5.00 4.50 7.50 4.50 4.00 3.75 3.25 4.50 4.00 3.75 3.25 3.00 4.00 3.00 2.75 2.25	100% 90% 80% 75% 60% 50% 14.00 12.00 10.00 8.50 7.00 6.00 12.00 10.00 8.00 7.00 6.00 5.25 10.00 8.50 7.50 6.75 5.50 5.00 9.00 7.50 6.50 5.50 5.00 4.50 8.00 7.00 6.00 5.50 4.50 4.00 7.50 6.75 5.75 5.00 4.25 8.00 7.00 6.00 5.50 4.50 4.00 7.50 6.75 5.75 5.00 4.25 8.00 7.00 3.75 3.25 3.00 4.50 4.00 3.75 3.25 3.00 4.50 4.00 3.75 3.25 2.25

IRON HOISTING ROPES.

MADE OF 6 STRANDS OF 19 WIRES EACH, LAID AROUND A HEMP CORE.

Diameter of	Diamete	rs of Shear of	ves or Dru Life for V	ms in Fee arious Dia	t, Showin ameters.	ng Perce	ntages
Rope. Inches.	100%	90%	80%	75%	60%	50%	25%
1½ 1½ 1½ 1½ 1, 1, 1, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2,	12.00 10.00 9.00 8.00 6.75 6.75 5.00 4.50 3.50 3.00	11.00 9.00 7.75 6.75 6.00 6.00 4.75 3.75 3.25	9.00 7.50 6.50 5.50 5.00 5.00 4.00 3.25 3.00 2.00	7.50 7.00 5.75 5.00 4.75 4.50 3.75 3.00 2.75	6.00 5.25 4.50 4.25 4.00 4.00 3.00 2.75 2.00	5.00 4.75 4.00 3.50 8.25 3.00 2.75 2.25 1.50 1.25	3.00 4.00 3.50 3.00 2.75 2.50 2.00 1.75 1.00

Wire rope is as pliable as new hemp rope of the same strength; the former will therefore run on the same sized sheaves and pulleys as the latter. But the greater the diameter of the sheaves, pulleys, and drums, the longer wire rope will last. In the construction of machinery for wire rope, it will be found good economy to make the drums and sheaves as large as possible.

The tables of wire-rope manufacturers give "proper diameters of drum or stare" at from 50 to 65 times the rope diameter; but the expression would more properly be the "minimum admissible diameter." For ordinary service, by using sheaves and drums from 75 to 100 times the diameter of the rope, the average life of hoisting ropes would be materially lengthened. For rapid hoisting, during which abnormal strains are most likely to occur, or where a low factor of safety is employed, a sheave diameter of ,150 times that of the rope is to be recommended.

Experience has demonstrated that the wear increases with the speed. It is therefore better to increase the load than the speed. Wire rope is manufactured either with a wire or a hemp center. The latter is more pliable than the former, and will wear better where there is short bending.

Wire rope must not be coiled or uncoiled like hemp rope. When mounted on

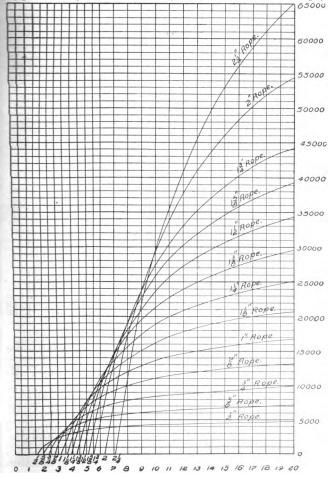
a reel, the latter should be mounted on a spindle or flat turntable to pay off the rope. When forwarded in a small coil, without reel, roll it over the ground like a wheel, and run off the rope in that way. All untwisting or booking must be avoided.

PROPER WORKING LOAD

PROPER WORKING LOAD FROM THE PROPER WORKING LOAD FOR Steel hoisting ropes, made with 19 wires to the strand, when used on rums of different diameters. Total strain of wire rope, including bending train and the strain due to load, assumed at 50,000 lb. per sq. in. of actual teel section. d = diameter of rope in in.; D = diameter of drum in in.; I = strain per sq. in. due to bending; L = proper working load in pounds. $S = 1,894,000 \times \frac{d}{D}$. $L = 20,000 \ d^2 - 757,600 \times \frac{d^3}{D}$.

$$S = 1,894,000 \times \frac{d}{D}$$
. $L = 20,000 d^2 - 757,600 \times \frac{d^3}{D}$.

(By permission of E. T. Sederholm, Chief Engr., Fraser & Chalmers, Chicago.)



Starting Strain on Hoisting Rope.—In selecting a hoisting rope, due al ance must be made for the shock and extra strain imposed on the rope with the load is started from rest. Experiments made by placing a dynamous between the rope and the cage have shown that starting stress may be two to three times the actual load.

Experiment 1.	Strain in Re Pounds.		
Empty cage, lifted gently	4,030 5,600 8,950 12,300		

Experiment 2.	Strain in Rope Pounds.
Cage and loaded cars, as weighed	11,300
Cage and loaded cars, lifted slowly and gently Cage and loaded cars, started with 3 in. of slack rope	11,525
Cage and loaded cars, started with 3 in. of slack rope	19,025
Cage and loaded cars, started with 6 in. of slack rope Cage and loaded cars, started with 9 in. of slack rope	24,625
Cage and loaded cars, started with 9 in. of slack rope	26,850

Horsepower of Manila Ropes. (Link-Bell Engineering Co.)

of it per of.	nt per ot.	king dn.	king dn.	Breaking Strain.	king vin.	king dn.	king dn.	ring sin.	1,000 per			Ft. Min.) Ft. Min.		Ft. Min.	5,000 per	Ft. Min.
Diam. (Rope.	Weight Foot.	Brea	Working Strain.	н. Р.	Tens. Wt.	н. Р.	Tens. Wt.	й. Р.	Tens. Wt.	н. Р.	Tens. Wt.	н. Р.	Tens. Wt.					
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	0.15 0.18 0.27 0.33 0.45 0.50 0.65 0.73 0.82 1.08 1.27	4,000 5,000 7,500 9,000 12,250 14,000 18,062 20,250 25,000 30,250 36,000	121 151 227 272 371 424 547 613 760 916 1,000	21/4 22/4 41/4 55 7 8 10/4 11/4 17 20/8	90 110 170 200 280 320 410 460 570 680 810	41/2 51/2 51/2 51/2 51/2 51/2 51/2 51/2 5	90 110 170 200 270 310 400 440 550 660 790	6\frac{1}{4} 7\frac{3}{4} 11\frac{3}{4} 11\frac{3}{4} 19 22 28\frac{1}{4} 39\frac{1}{4} 47\frac{1}{4} 56\frac{1}{6}	80 100 160 180 250 290 370 420 520 630 740	71 91 141 171 231 27 341 39 49 581 691	80 100 150 170 230 270 350 390 490 580 670	81 101 16 19 26 291 381 431 551 641	70 90 130 150 210 240 310 350 448 520 620					

WIRE-ROPE FASTENINGS.

Thimble spliced, in ordinary style, is shown in Fig. 1 (a). In this method, the wires, after being frayed out at the end and the rope bent around the thimble, are laid snugly about the main portion of the rope and securely fastened by wrapping with stout wire, the extreme ends that project below this wrapping being folded back, as shown.

Another style of thimble splicing is shown in Fig. 1 (b). In this case the strands are interlocked as in splicing, and the joint is wrapped with wire as in the former method. The socket fastening is shown in Fig. 1 (c). The hole in which the rope end is fastened is conical in shape. The rope is generally secured by fraying out the wires at the end, the interstices being filled up with spikes driven in tightly. The whole is finally cemented by pouring in molten Babbitt metal. This makes a much neater fastening than either of those shown in (a) and (b), but it does not possess anything like as much strength. The thimble possesses a serious disadvantage; it is usually made of a piece of curved metal bent around into an oval shape,

as shown in (a) and (b), with the groove, in which the rope lies, outside, the ends coming together in a sharp point. When weight is placed on the rope, the strain on the thimble is apt to cause one end to wedge itself

beyond or past the other, and with its sharp edge it cuts the strands in the splice. Mr. William Hewitt, of Trenton, N. J., while testing the strength of wire ropes, discovered this tendency, and experimented with sockets with the idea of devising some method of fastening the rope securely in the socket. He found that by adopt-ing the following plan he secured good results:

The wires, after being frayed out at the end, were bent upon themselves in hook fashion, the prongs of some being longer than others, so that the bunch would conform to the conical aperture of the socket, and the melted Babbitt metal was finally run in as usual. The rope was subjected to a strain of over 129,000 lb., and the wires in the socket were unaffected. The simplicity of this method commends itself to practical men.

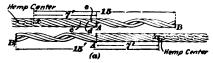






RAPID METHOD OF SPLICING A WIRE ROPE.*

The only tools needed are a cold cutter and hammer for cutting and trimming the strands, and two needles 12 in. long, made of good steel and tapered ovally to a point. Cut off the ends of the ropes to be spliced and unlay three adjacent strands of each back 15 ft.; cut out the hemp center to this point and relay the strands for 7 ft. and cut them off. Pull the ropes by each other until they have the position shown in Fig. 2 (a), cut off a and d', b and c', Fig. 2 (b), making their lengths approximately 10 and 12½ ft., respectively, measured from the point where the hemp centers were cut. Place the ropes together, Fig. 2 (b); unlay c, d, c, Fig. 2 (a), keeping the strands together, and follow with c', d', c', Fig. 2 (b). Similarly,



d', c', Fig. 2 (b). Similarly, unlay f', a', b', Fig. 2 (b), and follow with f, a, b, until the rope appears as in Fig. 2 (c). Next run the strands into the middle of To do this, cut the rope.

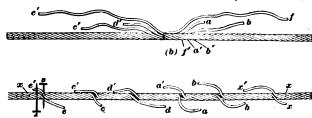
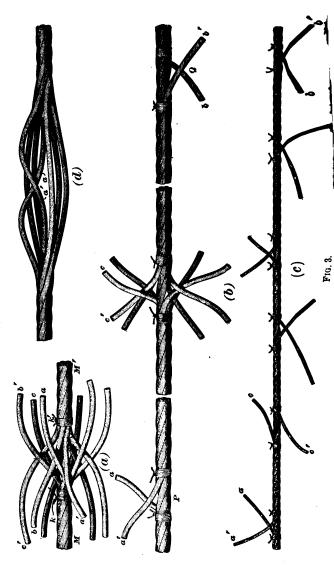


FIG. 2.

off the end of the strand c', Fig. 2 (c), so that when it is put in place it will just reach to the end x of the hemp core, and then push the needle A, Fig. 2 (c), through the rope from the under side, leaving two strands at the front of the needle, as shown. Push the needle B through from the upper side and as close to the needle A as possible, leaving the strands e and e' between them; place the needle A on the knee and turn the needle B around with the coil of the rope, and force the strand e' into the center of the rope. Repeat this

^{*} W. H. Morris, "Mines and Minerals," September, 1898.



ation with the other ends and cut them off so that the ends coming ther in the center of the rope will butt against each other as nearly as

ORDINARY LONG SPLICE.

Isols Required.—One pair wire nippers, for cutting off strands; one pair is, for pulling through and straightening ends of strands; two marlineses, one round and one oval, for opening strands; one knife to thempser; two clamps, to untwist rope to insert ends of strands, or, in place of m, two short hemp-rope slings, with a stick for each as a lever; a wooden llet and some rope twine. Also, a bench and vise are handy.

The length of the splice depends on the size of the rope. The larger ropes whire the longer splices. The splice of ropes from \$\frac{1}{2}\$ in. to \$\frac{1}{2}\$ in. in diameter buld not be less than 20 ft.; from \$\frac{1}{2}\$ in. to \$1\frac{1}{2}\$ in., 30 ft.; and from \$1\frac{1}{2}\$ in.

, 40 ft.
To splice a rope, tie each end with a piece of cord at a distance equal to e-half the length of the splice, or 10 ft. back from the end, for a \(\) "rope, after aich unlay each end as far as the cord. Then cut out the hemp center, ad bring the two ends together as close as possible, placing the strands of e one end between those of the other, as shown in Fig. 3 (a). Now remove second k from the end M of the rope, and unlay any strand, as a, and follow it with the strand of the other end M of the rope that corresponds to it, as with the straint of the other call m of the rope that corresponds to it, k. Fig. 3 (a). About 6 in, of a are left out, and a is cut off about 6 in, from the ppe, thus leaving two short ends, as shown at P in Fig. 3 (b), which must be ad for the present by cords as shown. The cord k should again be wound round the end M of the rope, Fig. 3 (a), to prevent the unraveling of the rands; after which remove the cord k on the other or M end of the rope above the straint k follow it in as above with the straint k. and unlay the strand b; follow it up, as above, with the strand b, leaving be ends out, and tying them down for the present, as before described in be case of strands a and a', see Q. Fig. 3 (b); also, replace the cord b for the me purpose as stated above. Now, again remove the cord b and unlay the strand of the first strands of the first stra me purpose as stated above. Now, again remove the cord k and unlay the sext strand, as c. Fig. 3 (a), and follow it up with c', stopping, however, this time within 4 ft. of the first set. Continue this operation with the remaining 6 strands, stopping 4 ft. short of the preceding set each time. The strands are now in their proper places, with the ends passing each other at intervals of 4 ft., as shown in Fig. 3 (c). To dispose of the loose ends, clamp the rope in a vise at the left of the strands a and a', Fig. 3 (c), and fasten a clamp to the rope at the right of these strands; then remove the cords tied around the rope that hold these two strands down; after which turn the clamp in the opposite direction to which the rope is twisted, thereby untwisting the rope, as shown in Fig. 3 (d). The rope should be untwisted enough to allow its hemp core to be pulled out with a pair of nippers. Cut off 24 in. of the hemp core, 12 in. at each side from the point of intersection of the strands a and a', and push the ends of the strands in their place, as shown in Fig. 3 (d). Then allow the rope to twist up to its natural shape, and remove the clamps. After the rope has been allowed to twist up, the strands tucked in generally bulge out somewhat. This bulging may be reduced by lightly tapping the bulged part of the strands with a wooden mallet, which will force their ends farther into the rope. Proceed in the same manner to tuck in the other ends of the strands.

CHAINS.

The links of iron chains are usually made as short as is consistent with easy play, so as to make them less liable to kink, and also to prevent bending when wound around drums, sheaves, etc.

The weight of close-link chain is about three times the weight of bar from

which it is made, for equal lengths.

Karl von Ott, comparing weight, cost, and strength of three materials, hemp, iron wire, and chain iron, concludes that the proportion between cost of hemp rope, wire rope, and chain is as 2:1:3, and that, therefore, for equal resistances, wire rope is only half the cost of hemp rope, and a third of cost of chains.

Chains of warranted superior iron will stand 25% more strain before eaking. The report of the U. S. Test Board, 1881, shows that the ultimate strength of chains may be taken at 1.6 that of the iron from which the links

are made.

The strength of chains varies, owing to the nature of the iron from which they are made, and their mechanical construction. The following table is approximately correct for ordinary iron chains:

TABLE OF WEIGHT AND STRENGTH OF CHAINS.

Diameter of Rod of Which the Links Are Made. Inches.	Weight of Chain per Running Foot. Pounds.	Working Strength. Tons.	Breaking Strain. Tons.	Diameter of Rod of Which the Links Are Made. Inches.	Weight of Chain per Running Foot. Pounds.	Working Strength. Tons.	Breaking Strain. Tons.
of the Court of th	.325 .579 .904 1.30 1.78 2.31 2.93 3.62 4.38 5.21	.19 .36 .45 .85 1.09 1.43 1.80 2.23 2.70 3.21	.773 1.37 2.14 3.09 4.20 5.50 6.96 8.58 10.39 12.36	75 1 11 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	7.10 8.14 9.26 11.70 14.50 17.50 20.80 24.40 28.40 32.60	4.40 5.00 5.71 7.23 9.00 10.80 13.00 15.24 17.65 20.27	16.80 19.32 22.00 26.44 32.64 39.42 47.00 55.14 63.97 73.44

HYDROSTATICS.

Hydrostatics treats of the equilibrium of liquids, and of their pressures on the walls of vessels containing them; the science depends on the way in which the molecules of a liquid form a mass under the action of gravity and molecular attraction, the latter of which is so modified in liquids as to give them their state of liquidity. While the particles of a liquid cohere, they are free to slide upon one another without the least apparent friction; and it is this perfect mobility that gives them the mechanical properties considered in hydrostatics.

The fundamental property may be thus stated: When a pressure is exerted

The fundamental property may be thus stated: In the to pressure to exercise on any part of the surface of a liquid, that pressure is transmitted undiminished to all parts of the mass, and in all directions. This is a physical axiom, and on it are based nearly all the principles of hydrostatics.

Equilibrium of Liquids.—This is a property of liquids that can be easily demonstrated, and examples are frequently seen. Thus, if two barrels are connected at the bottom with a pipe, and water is poured in one until it reaches within a foot of the top, the water in the other will be found to have reaches within a foot of the top, the water in the other will be found to have

reaches within a foot of the top, the water in the other will be found to have attained the same height.

Pressure of Liquids on Surfaces.—The general proposition on this point is as follows: The pressure of a liquid on any surface immersed in it is equal to the weight of a column of the liquid whose base is the surface pressed, and whose height is the perpendicular depth of the center of gravity of the surface below the surface of the liquid. The pressure thus exerted is independent of the shape or size of the vessel or cavity containing the liquid.

The pressure of a liquid against any point of any surface, either curved or plane, is always perpendicular to the surface at that point.

At any given depth the pressure of a liquid is equal in every direction, and is in direct proportion to the vertical depth below the surface.

The weight of a cubic foot of fresh water, at ordinary temperature of the

The weight of a cubic foot of fresh water, at ordinary temperature of the atmosphere, that is, from 32° F. to 80° F., is usually assumed at 62.5 lb. This is a trifle more than the actual weight, but is sufficiently close for purposes of calculation.

To Find the Pressure Exerted by Quiet Water Against the Side of a Gangway or Heading .- Multiply the area of the side in square feet by the perpendicular distance from the surface of the water to a point equidistant between the top and bottom of the submerged heading or gangway, and multiply the product by 62.5. The result will be the pressure in pounds, exclusive of atmospheric pressure. This latter need not be considered in ordinary mining work.

EXAMPLE.—If an abandoned colliery, opened by a slope on a pitch of 250 d 190 yd. long, is allowed to fill with water, what is the average pressure erted on each square foot of the lower rib of the gangway, assuming at the gangways were driven dead level, and that the length of the slope s measured to a point on the lower rib equidistant between top and

ttom of gangway.

We here have a perpendicular height of water $=300 \times \sin$ of 25° 126.78 ft. Then, the pressure on each square foot of the lower rib of ngway $=126.78 \times 62.5$ lb., or the weight of 1 cu. ft., or a pressure on each nare foot of surface of 7,923.75 lb., or over $3\frac{1}{6}$ gross tons. The total pressure certed along the gangway may readily be found by multiplying the 23.75 lb. by the number of square feet of the lower rib against which

To find the total pressure of quiet water against and perpendicular to any rface whatever, as a dam, embankment, or the bottom, side or top of any ntaining vessel, water pipe, etc., no matter whether said surface be ertical, horizontal, or inclined; or whether it be flat or curved; or whether

reach to the surface of the water or be entirely below it:

Multiply the area, in square feet, of the surface pressed, by the vertical depth in et of its center of gravity below the surface of the water, and this product by 62.5.

The result will be the pressure in pounds.

Thus, assuming that in the annexed three figures the depth of water in ach dam is 12 ft., and the wall or embankment is 50 ft. long, then in Fig. 1 the total pressure will equal $12 \times 50 \times 6 \times 62.5 = 225{,}000$ lb.

In Figs. 2 and 3 the walls or embankments, being inclined, expose a greater surface to pressure, say 18 ft. from A to B. Then the total pressure satus $18 \times 50 \times 6 \times 62.5 = 337,500$ lb.

Now, the results obtained are the total pressures without regard to direction.









In Fig. 1 the total pressure calculated, or 225,000 lb., is horizontal, tending either to overturn the wall or make it slide on its base. The center of pres-

In Fig. 2 the pressure is exerted in two directions; one pressure, acting horizontally, tends to overthrow or slide the wall, while the other, acting

vertically, tends to hold it in place.

In Fig. 3 the pressure is also exerted in two directions; one pressure, acting horizontally, tends to overthrow or slide the wall, while the other

So long as the vertical depth of water remains the same, the horizontal pressure remains the same, no matter what inclination is given the wall. Thus, in Figs. 2 and 3, the horizontal pressure is the same as in Fig. 1,

or 225,000 lb.

The total pressure of the water is distributed over the entire depth of the submerged part of the back of the wall, and is least at the top, gradually increasing toward the bottom. But so far as regards the united action of every portion of it, in tending to overthrow the wall, considered as a single mass of masonry, incapable of being bent or broken, it may all be assumed to be applied at C, which is one-third of the vertical depth from the bottom in Fig. 1, or, what is the same thing, one-third of the

slope distance from the bottom in Figs. 2 and 3.

No matter how much water is in a dam or vessel, the pressure remains the same, so long as the area pressed and the vertical depth of its center of gravity below the level surface of the water remains un-Thus, if the water in dam shown in Fig. 1 changed. extended back 1 mile, it would exert no more pressure against the wall than if it extended back only 1 ft.

In any two vessels having the same base, and containing the same depth of water, no matter what quantity, the pressures on the bases are equal. Thus, quantity, the pressures on the bases are equal. Thus, if Figs. 4 and 5 have the same base and be filled with



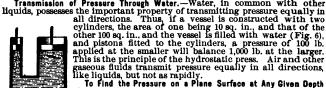
FIG. 4. FIG. 5.

water to the same depth, the pressure on the bases will be equal. This fact, that the pressure on a given surface, at a given

depth, is independent of the quantity of water, is called the hydrostatic paradox.

As the pressure of water against any point is at right angles to the surface at that point, it follows that props or other strengthening material for the strengthening of such structures as a sloping dam, should be so placed as to offer the greatest resistance in a line at right angles to the sloping surface, and these supports should be strongest and closest together at the bottom. For the same reason, the hoops on a circular tank should be strongest and closest at the bottom.

Transmission of Pressure Through Water.-Water, in common with other



To Find the Pressure on a Plane Surface at Any Given Depth of Water.—For pounds per square inch, multiply depth in feet by .434. For pounds per square foot, multiply depth in feet by .62.5. For tons per square foot, multiply depth in feet by .0279. The pressure per square foot at different

FIG. 6. depths increases directly as the depths. The total pressure against a plane 1 ft. wide at different depths increases as the square of the depths.

PRESSURE IN POUNDS PER SQ. FT. AT DIFFERENT VERTICAL DEPTHS, AND ALSO THE TOTAL PRESSURE AGAINST A PLANE I FT. WIDE EXTENDIBLY VERTICALLY FROM THE SUFFACE OF THE WATER TO THE SAME DEPTHS.

Depth. Feet.	Pressure. Pounds per Sq. Ft.	Total Pressure. Pounds.	Depth. Feet.	Pressure. Pounds per Sq. Ft.	Total Pressure. Pounds.	Depth. Feet.	Pressure. Pounds per Sq. Ft.	Total Pressure. Pounds.
1	62.5	31	. 27	1,687	22,781	65	4,062	132,02
	125	125	28	1,750	24,500	70	4,375	153,12
3	187	281	29	1,812	26,281	75	4.687	175,779
4	250	500	30	1,875	28,125	80	5,000	200,000
2 3 4 5 6 7 8 9	312	781	31	1,937	30,031	85	5,312	225,77
6	375	1,125	32	2,000	32,000	90	5,625	253,124
7	437	1,531	33	2,062	34,031	95	5,937	282,025
8	500	2,000	34	2,125	36,125	100	6,250	312,500
9	562	2,531	35	2,187	38,281	110	6,875	378,124
10	625	3,125	36	2,250	40,500	120	7,500	450,000
11	687	3,781	37	2,312	42,781	130	8,125	528,100
12	750	4,500	38	2,375	45,125	140	8,750	612,496
13	812	5,281	39 .	2,437	47,531	150	9,375	703,116
14	875	6,125	40	2,500	50,000	160	10,000	800,000
15	937	7,031	41	2,562	52,531	170	10,625	903,100
16	1,000	8,000	42	2,625	55,125	180	11,250	1,012,496
17	1,062	9,031	43	2,687	57,781	190	11,875	1,128,100
18	1,125	10,125	44	2,750	60,500	200	12,500	1,250,000
19	1,187	11,281	45	2,812	63,281	225	14,062	1,582,025
20	1,250	12,500	46	2,875	66,125	250	15,625	1,953,100
21	1,312	13,781	47	2,937	69,031	275	17,187	2,363,275
22	1,375	15,125	48	3,000	72,000	300	18,750	2,812,500
23	1,437	16,531	49	3,062	75,031	350	21,875	3,828,100
24	1,500	18,000	50	3,125	78,125	400	25,000	5,000,000
25	1,562	19,531	55	3,437	94,531	450	28,120	6,328,100
26	1,625	21,125	60	3,750	112,500	500	31,250	7,812,500

Pressure of Water in Pipes.-As water exerts a pressure equally in all directions, it is important that in pipe lines the pipe should be sufficiently hick to assure strength enough to resist a bursting pressure. In ordinary rtice, the thickness of cast-iron water pipes of different bores is calculated Mr. J. T. Fanning's formula, given in his Hydraulie Engineering, which is follows:

Thickness in inches =
$$\frac{(\text{pressure in lb. per sq. in.} + 100) \times \text{bore in in.}}{.4 \times \text{ultimate tensile strength}} + .333 \left(1 - \frac{\text{bore in in.}}{100}\right).$$

This formula, worked out for different heads and different sizes of bore, and the following results:

THICK NESS OF PIPE FOR DIFFERENT HEADS AND PRESSURES.

50 100 200

	a dibunto	dansirday av	Table 1	000		-,000
ressure in Lb. per Sq. In.	21.7	43.4	86.8	130	217	434
fore. Inches.		Thi	ickness of l	Pipe. Inc	hes.	
2 3 4 6 8 10 12 16 18 20 24 30 36 48	.36 .37 .39 .41 .45 .47 .49 .55 .57 .61 .66 .74 .82	.37 .38 .40 .43 .47 .50 .53 .60 .63 .67 .73 .83 .93 1.13	.38 .40 .42 .47 .52 .56 .60 .70 .74 .79 .87 1.01 1.15 1.42	.39 .42 .45 .50 .57 .62 .67 .79 .85 .91 1.02 1.19 1.36 1.70	.42 .45 .50 .57 .66 .74 .82 .98 1.06 1.15 1.30 1.55 1.80 2.28	.48 .54 .61 .75 .90 1.04 1.18 1.46 1.60 1.75 2.03 2.46 2.88 3.73

In the above table, the ultimate tensile strength of cast iron is taken at 18,000 lb. per sq. in. The addition of 100 lb. to the pressure is made to allow for water ram. The valves of water pipes should be closed slowly, and the necessity of this increases as the pipes increase in diameter. If this rule is not observed, the momentum of the running water is arrested suddenly, and a great pressure is created against the pipes in all directions, and throughout the entire length of the line above the valve, even if it be many miles, and there is danger of their bursting at any point. For this reason, stopgates are shut by screws, because they prevent any very sudden closing; but in pipes of large diameters, even the screws must be worked very slowly to prevent bursting.

Compressibility of Liquids.—Liquids are not entirely incompressible, but they are so nearly so, that for most purposes they may be considered as incompressible. The bulk of water is diminished about $\frac{1}{1000}$ by a pressure of 324 lb. per sq. in., or 22 atmospheres; varying slightly with its temperature. It is perfectly elastic, regaining its original bulk when the pressure is.

removed.

Construction of Dams in Mines.—Dams may be constructed in mines, either to isolate a portion of the workings so that they can be flooded to extinguish fires, or, in cases where an extremely wet formation has been penetrated, it is sometimes expedient to construct a dam so as to prevent the water from flowing into the workings. Mine dams should be of sufficient strength to resist any column of water that will be likely to come against them. The dam should be arched toward the direction from which the pressure comes, and should be given a good firm bearing in both walls and in the floor and roof. Fig. 7 illustrates a brick dam that was constructed in Kehley's Run Colliery, at Shenandoah, Pa., to isolate a portion of the seam so that it might

be flooded to extinguish a mine fire. This is one of the largest mine dams that has ever been constructed. It is composed of three brick arches, each having a thickness of 5 ft., that are placed one against the other so that they act as one solid structure. The gangway at this point is about 20 ft. wide and the distance to the next upper level is about 119 ft. It was intended that this should be the maximum head of water that the dams would ever have to resist, though they were made sufficiently strong to resist a head of water reaching to the surface. The separate walls were constructed one at a time, and the cement allowed to set before the next wall was placed. The back wall was carried to a greater depth and height than the others, so as to make sure of the fact that all slips or partings had been closed. The total pressure upon the dam when the water was in the mine was about 70,000 lb. per sq. ft.

Dams constructed to permit the flooding of a mine usually require no passages through them, but where dams are constructed to confine the water to certain parts of the workings, and so reduce pumping charges, it may be necessary to provide both manways and drain pipes through the

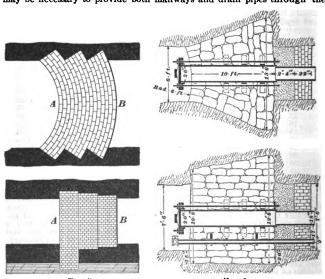


Fig. 7.

FIG. 8.

dams. Fig. 8 illustrates a plan and cross-section of a dam in the Curry Mine, at Norway, Mich. ("Mines and Minerals," Vol. 18, page 177; Trans. A. I. M. E., XXVII, 402), constructed to keep the water that came from some exploring drifts out of the mine workings. As originally constructed, it consisted of a sandstone dam 10 ft. thick and arched on the back face with a radius of 6 ft. A piece of 20" pipe provided a manway through the masonry and was held in place by three sets of clamps and bolts passing through the stonework. A 5" drain pipe was also carried through the dam and secured by clamps. When the pressure came upon the dam it was found to leak so the water was drained off and a 22" brick wall built 2 ft. 4 in. back of the dam, the space between being filled with concrete, and the manway and drain pipe extended through the brick wall. Before closting the drain pipe, horse manure was fastened against the face of the brick wall by means of a plank partition. After this the manway and drain pipe weals as mall

unt, but the but this soon practically ceased, showing that the manure had A gauge in the head of the manway on this dam showed a sure of 211 lb., which corresponded to a static head of 640 ft. of water. total pressure against the dam was something over 800 tons, which it essfully resisted.

HYDRAULICS.

Hydraulics treats of liquids in motion, and in this, as in hydrostatics, **ter is taken as** the type. In theory its principles are the same as those of ling bodies, but in practice they are so modified by various causes that cannot be relied on except as verified by experiment. The discrepancy es from changes of temperature that vary the fluidity of the liquid, from ction, the shape of the orifice, etc. As we shall deal with water only, the cause may be thrown aside as of little account.

In theory the velocity of a jet is the same as that of a body falling from the

rface of the water.

To Find the Theoretical Velocity of a Jet of Water.—Let v = the velocity, y = the acceleration of gravity (32.16 ft.), and d = the distance of the orifice **elow the surface of the water.**

Then, $v = \sqrt{2gd}$, or v = the square root of twice the product of $g \times d$. Example.—The depth of water above the orifice is 64 ft.; what is the relocity?

Substituting 64 for d, and 32.16 for g, we have, $v = \sqrt{2 \times 32.16 \times 64}$, or

64.16.

To Find the Theoretical Quantity of Water Discharged in a Given Time.—Multiply the area of the orifice by the velocity of the water, and that product by the number of seconds.

EXAMPLE.—What quantity of water will be discharged in 5 seconds from

an orifice having an area of 2 sq. ft., at a depth of 16 ft.?

 $\sqrt{2 \times 32.16 \times 16} \times 2 = 64.16$ cu. ft., or the amount discharged in 1 second, and in 5 seconds the amount will be $5 \times 64.16 = 320.8$ cu. ft.

The above rules are only theoretical, and are only useful as foundations

on which to build practical formulas.

Flow of Water Through Orifices.—The standard orifice, or an orifice so arranged that the water in flowing from it touches only a line, as would be the case in flowing through a hole in a very thin plate, is used for the measurement of water. The contraction of the jet, which always occurs when water issues from a standard orifice, is due to the circumstance that the particles of water as they approach the orifice move in converging directions, and that these directions continue to converge for a short distance beyond the plane of the orifice. This contraction causes only the inner corner of the orifice to be touched by the escaping water, and takes place in orifices of any shape, its cross-section being similar to the orifice until the place of greatest contraction is passed. Owing to this contraction, the actual discharge from an orifice is always less than the theoretical discharge.

The Coefficient of Contraction.—The coefficient of contraction is the number by which the area of the orifice is to be multiplied in order to find the area of the least cross-section of the jet. In this way by experiment this coefficient has been found to be about .62 (Merriman's "Hydraulics"); or, in other words, the minimum cross-section of the jet is 62% of the cross-section

of the orifice.

The Coefficient of Velocity.—The coefficient of velocity is the number by which the theoretical velocity of flow from the orifice is to be multiplied in order to find the actual velocity at the least cross-section of the jet. This

may be taken for practical work as .98; or, in other words, the actual flow at the contracted section is 98% of the theoretical velocity.

The Coefficient of Discharge.—The coefficient of discharge is the number by which the theoretical discharge is to be multiplied in order to obtain the actual discharge. This has been found by thousands of experiments to be equal to the product of the coefficients of contraction and velocity, and for practical work it may be taken as .61; or, the actual discharge from standard orifices is 61% of the theoretic discharge.

NOTE.—While the coefficients for standard orifices with sharp edges have been determined fairly close, those for the more complicated cases of weirs, and especially for the flow of water through long pipes, are simply the nearest approximation to the truth that it has been possible to obtain. In all cases, the coefficient should be one that has been determined under conditions similar to those in the problem in hand. For instance, it is not practicable to use the coefficient for small pipes in solving problems relating to large ones, or for short pipes in solving problems relating to long ones.

Suppression of the Contraction.—When a vertical orifice has its lower edge at the bottom of a reservoir, the particles of water flowing through its lower portion move in lines nearly perpendicular to the plane of the orifice, and the contraction of the jet does not form on the lower side. The same thing occurs in a lesser degree when the lower edge of the orifice is within a distance of three times its least diameter from the bottom. The suppression of contraction will occur on the side if it is placed within a distance of three times its least diameter from the side of a reservoir, the suppression of contraction being the greater the nearer the orifice is to the side. By rounding the edge of the orifice sufficiently, the contraction can be completely suppressed, and the discharge can be increased. As stated before, the value of the coefficient of contraction for a standard square-edged orifice is .62, but with a rounded orifice it may have any value between .62 and 1.00, depending on the degree of rounding. The coefficient of discharge for square-edged orifices has a mean value of .61; this is increased with rounded edges and may have any value between .61 and 1.00, although it is not probable that values greater than 95 can be obtained except by the most careful adjustment of the rounded edges to the exact curve of a completely contracted jet. A rounded interior orifice is therefore always a source of error when the object of the orifice is the measurement of the discharge.

GAUGING WATER.

Water is sold by two methods; i. e., the flowing unit and the capacity unit. The flowing unit is a cubic foot per second. In the western part of North America the miners' inch has come into use quite largely, while in Australia and New Zealand the cubic foot per second is the common measure, 1 cu. ft. per second being 1 "head," and 10 heads of water would be 10 cu. ft. per second, regardless of the actual hydrostatic head under which the water was delivered. Water is sometimes sold for irrigation by the capacity unit, that is, so much land covered to a certain depth, as, for instance, the "acrefoot." which means that I acre has been covered to a depth of I foot, or that

an amount of 43,560 cu. ft. of water has been furnished.

Miners' inch.—The miners' inch may be roughly defined as the quantity of water that will flow in 1 minute through a vertical standard orifice having a section of 1 sq. in. and a head of 64 in. above the center of the orifice. quantity equals 1.53 cu. ft., and the mean quantity may be taken at, approximately, 1.5 cu. ft. per minute. The laws or customs defining the miners' inch in different districts vary so that the amount of water actually delivered inch in different districts vary so that the amount of water actuarly derivered varies from 1.2 to 1.76 cu. ft. per minute, the principal reasons for these variations being the method adopted for measuring the water where large quantities are used; as, for instance, at Smartsville, in California, an opening 4 in deep, 250 in. long, with a head of 7 in. above the top edge, is said to furnish 1,000 miners' inches, while it would actually furnish considerably over 1,000. In other places, the size of the opening for measuring the amounts is restricted, and may actually furnish less than the rated amount. In Montans the common method of measurement was formerly through a vertical rectangle 1 in. high, with a head on the center of the orifice of 4 in. The number of miners' inches discharged was considered to be the same as the number of linear inches in the length of the orifice; thus, under the given head, an orifice 1 in. deep and 60 in. long could discharge 60 miners' inches.

The State Legislature of Montana has now passed a law defining the miners' inch as the number of gallons of water discharged in a given time, regardless of the character of the openings or methods of measurement. The statement is as follows: "Where water rights, expressed in miners' inches, have been granted, 100 miners' inches shall be considered equivalent to a flow of 21 cu. ft. (18.7 gal.) per second, and this proportion shall be observed in determining the equivalent flow represented by any number of

miners' inches.'

If this amount is reduced to cubic feet per minute, it will be found to be equal to a flow of 1.5 cu. ft. per minute, which is the value given above

for the miners' inch.

Duty or Work Performed by a Miners' Inch of Water.—Few tests have been made in regard to the duty of a miners' inch of water, but the North Bloomfield mine and the La Grange mine, in California, have carried on a series of experiments extending over several years. At the La Grange mine the observations were carried on simultaneously upon several different claims, hence parallel dates appear. The accompanying tables give the results of these experiments. In general it is governed by the size, capacity, character of pavement, and grade of sluices, together with the supply of water. A heavy grade will compensate for a limited supply. With an abundant supply of water and material, the capacity of the sluices will depend on: First, the character of the material washed; second, the size and minimum grade of the sluices; third, the character of the riffies used.

DUTY OF MINERS' INCH.
(Risdon Iron Works, Evans's Elevator Catalogue.)
NORTH BLOOMFIELD MINE.

Years.	Cubic Yards of Gravel Washed,	Miners' 24-Hour Inches.	Grades.	Cubic Yards Washed per Miners' Inch.	Cubic Feet of Water Used per Cubic Feet of Gravel Moved.	Height of Bank.	Remarks.
1870-74	3,250,000	710.987	6½ in, to 12 ft,	4.60	18	100 ft.	Sluices 6 ft. wide,
1875	1,858,000	886,972	614 in. to 12 ft.	4.80	17	100 ft	Riffles principally
1876	2,919,700	700,000	614 in to 12 ft.	4.17	20	200 ft.	blocks (wood), but
1877	2,993,930	595,000	6½ in. to 12 ft.	3,86	21	265 ft.	rock riffles in tail sluices. The larger portion
Totals	11,021,630	2,392,959		4.60 18	18		of the material moved was top gravel.
			La Gra	NGE I	INE.		
1874-76	676,968	624.745	4 in. to 16 ft.	1.08	74.0	10 to 48 ft.]
1875-76	683,244	875,155	4 in. to 16 ft.	1.82	43.9	6 ft.	Sluices 4 ft. wide
1874-76	284,932	207,010	4 in. to 16 ft.	1.37	58.0	50 to 80 ft.	and 30 in. deep,
1875-78	459,570	302,960	4 in. to 16 ft.	1.52	52.0	40 to 50 ft.	blocks.
1880-81	329,120	203,325	4 in, to 16 ft.	1.57	50.0	10 to 80 ft.	
Totals	2,433,834	1,713,195		1.42	56.0		

The right-angled \forall notch is frequently used for gauging the flow of comparatively small streams. The notch is usually fitted into a box provided with baffle boards, Fig. 9, or where this is not practicable the water should be so impounded above the notch as to remove all possibility of surface currents producing a perceptible velocity of approach. The distance a of the surface of the water below the top of the box is taken at a point some distance back from the notch (at least 18 to 20 in.), where the surface of the water is unaffected by the flow through the notch. The distance a, subtracted from the total depth of the notch H, gives the head h of the water passing over the notch. The discharge in cubic feet per second may be found by the formula

 $Q = .306 \, v \, \overline{h^5} = .306 \, h^2 \, v \, h$

in which Q equals the quantity in cubic feet per minute and h equals the

head in inches. The accompanying table gives the discharge in cubic feet per minute through a right-angled V notch, as shown in Fig. 9, for heads varying from 1.05 in. to 12 in.

TABLE 1.

DISCHARGE OF WATER THROUGH A RIGHT-ANGLED V NOTCH.

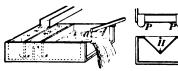
	<u> </u>		1	I	i			<u> </u>	
A Head. Inches.	Quantity per Min. Cu. Ft.	h Head. Inches.	Q Quantity per Min. Cu. Ft.	h Head. Inches.	Q Quantity per Min. Cu. Ft.	A Head. Inches.	Q Quantity per Min. Cu. Ft.	h Head. Inches.	Q Quantity per Min. Cu. Ft.
1.05	0455	0.07	F 007	5.45	21.22	7.65	49.53	0.05	
1.05 1.10	.3457 .3884	3.25 3.30	5.827 6.054	5.50	21.22	7.70	50.34	9.85 9.90	93.18 94.37
1.15	.4340	3.35	6.285	5.55	22.20	7.75	51.16	9.95	95.56
1.15	.4827	3.40	6.523	5.60	22.70	7.80	51.10	10.00	96.77
1.25	.5345	3.45	6.765	5.65	23.22	7.85	52.83	10.05	97.98
1.30	.5896	3.50	7.012	5.70	23.74	7.90	53.67	10.10	99.20
1.35	.6480	3.55	7.266	5.75	24.26	7.95	54.53	10.15	100.43
1.40	.7096	3.60	7.524	5.80	24.79	8.00	55.39	10.10	100.43
1.45	.7747	3.65	7.788	5.85	25.33	8.05	56.26	10.25	102.92
1.50	.8432	3.70	8.058	5.90	25.87	8.10	57.14	10.30	104.18
1.55	.9153	3.75	8.332	5.95	26.42	8.15	58.03	10.35	105.45
1.60	.9909	3.80	8.613	6.00	26.98	8.20	58.92	10.40	106.73
1.65	1.0700	3.85	8.899	6.05	27.55	8.25	59.82	10.45	108.02
1.70	1.1530	3.90	9.191	6.10	28.12	8.30	60.73	10.50	109.31
1.75	1.2400	3.95	9.489	6.15	28.70	8.35	61.65	10.55	110.62
1.80	1.3300	4.00	9.792	6.20	29.28	8.40	62.58	10.60	111.94
1.85	1.4240	4.05	10.100	6.25	29.88	8.45	63.51	10.65	113.26
1.90	1.5220	4.10	10.410	6.30	30.48	8.50	64.45	10.70	114.60
1.95	1.6250	4.15	10.730	6.35	31.09	8.55	65.41	10.75	115.94
2.00	1.7310	4.20	11.060	6.40	31.71	8.60	66.37	10.80	117.29
2.05	1.8410	4.25	11.390	6.45	32.33	8.65	67.34	10.85	118.65
2.10	1.9550	4.30	11.730	6.50	32.96	8.70	68.32	10.90	120.02
2.15	2.0740	4.35	12.070	6.55	33.60	8.75	69.30	10.95	121.41
2.20	2.1960	4.40	12.420	6.60	34.24	8.80	70.30	11.00	122.81
2.25	2.3230	4.45	12.780	6.65	34.89	8.85	71.30	11.05	124.21
2.30	2.4550	4.50	13.140	6.70	35.56	8.90	72.31	11.10	125.61
2.35	2.5900	4.55	13.510	6.75	36.23	8.95	73.33	11.15	127.03
2.40	2.7300	4.60	13.890	6.80	36.89	9.00	74.36	11.20	128.45
2.45	2.8750	4.65	14.270	6.85	37.58	9.05	75.40	11.25	129.90
2.50	3.0240	4.70	14.650	6.90	38.27	9.10	76.44	11.30	131.35
2.55	3.1770	4.75	15.040	6.95	38.96	9.15	77.49	11.35	132.81
2.60	3.3350	4.80	15.440	7.00	39.67	9.20	78.55	11.40	134.27
2.65	3.4980	4.85	15.850	7.05	40.38	9.25	79.63	11.45	135.75
2.70	3,6660	4.90	16.260	7.10	41.10	9.30	80.71	11.50	137.23
2.75	3.8380	4.95	16.680	7.15	41.83	9.35	81.80	11.55	138.73
2.80	4.0140	5.00	17.110	7.20	42.56	9.40	82.90	11.60	140.23
2.85	4.1960	5.05	17.540	7.25	43.30	9.45	84.01	11.65	141.75
2.90	4.3820	5.10	17.970	7.30	44.06	9.50	85.12	11.70	143.28
2.95	4.5740	5.15	18.420	7.35	44.82	9.55	86.24	11.75	144.82
3.00	4.7700	5.20	18.870	7.40	45.58	9.60	87.37	11.80	146.36
3.05	4.9710	5.25	19.320	7.45	46.36	9.65	88.52	11.85	147.91
3.10	5.1780	5.30	19.790	7.50	47.14	9.70	89.67	11.90	149.48
3.15	5.3880	5.35	20.260	7.55	47.92	9.75	90.83	11.95	151.05
3.20	5.6050	5.40	20.730	7.60	48.72	9.80	92.00	12.00	152.64
	1	l		1		i	,		

1 cu. ft. contains 7.48 U. S. gallons; 1 U. S. gallon weighs 8.34 lb.

Gauging by Weirs.—A weir is an obstruction placed across a stream for the purpose of diverging the water so as to make it flow through a desired channel, which may be a notch or opening in the weir itself. The term usually applies to rectangular notches in which the water touches only the bottom and ends, the opening being a notch without any upper edge. Weirs are of two general classes: weirs with end contractions, Fig. 10 (a), and weirs without

end contractions, Fig. 10 (b). The crest and edges of the weir with end contractions should be sharp, as shown at a, Fig. 10 (c) and (d). The head of water H producing the flow over the weir should be measured at a sufficient distance from the crest to avoid the effects of the curve of the surface as it flows over the crest. The

water above the weir should be motionless, or if it has any perceptible current toward the weir, this should be determined and taken into account in the formula. Fig. 11 illustrates a weir constructed across a small stream for measuring its flow. The head is measured from the stake E some distance



back of the weir, the top of the stake being level with the crest of the weir B. The discharge over the weir may be calculated from the following formula:

Let l = length of weir in feet;

H = head in feet;

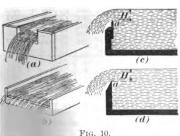
v = velocity with which the water approaches the weir in feet;

h = a head equivalent to the velocity with which the water approaches the weir:

coefficient of discharge;

theoretic discharge in cubic feet per second;

= actual discharge in cubic feet per second. For weirs with end contractions and a velocity of approach, the actual



discharge is $Q = 5.347 c l \sqrt{(H + \frac{3}{4}h)^3}$. Where the water has no

velocity of approach,

 $Q = 5.347 \, cl \, \sqrt{H^3}$ For weirs without end contractions, but with a velocity of approach, the actual discharge is

 $Q = 5.347 c l \sqrt{(H + 1.4 h)^3}$. Where the water has no velocity of approach,

 $Q = 5.347 \, c \, l \, \sqrt{H^3}$. The velocity with which the water approaches the weir

may be found by determining the approximate discharge ream without any allowance for velocity of approach, and then as discharge in cubic feet per second by the area of the stream in where it approaches the weir, which will give the velocity of

n feet per aving ob-value of v, lent head h and by the 11555 v2.

s small in sually negess great accuracy is required.

The values of coefficients of discharge, as determined from experiments for weirs with end contractions, are given in Table II,



Fig. 11.

and for weirs without end contractions in Table III. The values of the coefficients in Tables II and III are given in feet and tenths. Frequently

in measuring water where only a close approximation is required, it is desired to take all of the measurement in feet and inches. See Table IV.

TABLE II.

Values of the Coefficient of Discharge for Weirs With
End Contractions.

Effective Head.			Length	of Weir	. Feet.		
Feet.	.66	1	2	3	5	10	19
.10	.632	.639	.646	.652	.653	.655	.656
.15	.619	.625	.634	.638	.640	.641	.642
.20	.611	.618	.626	.630	.631	.633	.634
.25	.605	.612	.621	.624	.626	.628	.629
.30	.601	.608	.616	.619	.621	.624	.625
.40	.595	.601	.609	.613	.615	.618	.620
.50	.590	.596	.605	.608	.611	.615	.617
.50 .60	.587	.593	.601	.605	.608	.613	.615
.70		.590	.598	.603	.606	.612	.614
.80			.595	.600	.604	.611	.613
.90			.592	.598	.603	.609	.612
1.00			.590	.595	.601	.608	.611
1.20			.585	.591	.597	.605	.610
1.40			.580	.587	.594	.602	.609
1.60		1		.582	.591	.600	.607

TABLE III.

VALUES OF THE COEFFICIENT OF DISCHARGE FOR WEIRS WITHOUT END CONTRACTIONS.

Effective Head. Feet.	Length of Weir. Feet.										
	19	10	7	5	4	3	. 2				
.10	.657	.658	.658	.659							
.15	.643	.644	.645	.645	.647	.649	.652				
.20	.635	.637	.637	.638	.641	.642	.645				
.25	.630	.632	.633	.634	.636	.638	.641				
.30	.626	.628	.629	.631	.633	.636	.639				
.40	621	.623	.625	.628	.630	.633	.636				
.50	.619	.621	.624	.627	.630	.633	.637				
.60	.618	.620	.623	.627	.630	.634	.638				
.70	.618	.620	.624	.628	.631	.635	.640				
.80	.618	.621	.625	.629	.633	.637	.643				
.90	.619	.622	.627	.631	.635	.639	.645				
1.00	.619	.624	.628	.633	.637	.641	.648				
1.20	.620	.626	.632	.636	.641	.646					
1.40	.622	.629	.634	.640	.644						
1.60	.623	.631	.637	.642	.647						

TABLE IV.

WEIR TABLE GIVING CUBIC FEET DISCHARGED PER MINUTE FOR EACH INCH IN LENGTH OF WEIE FOR DEPTHS FROM 1 IN. TO 25 IN.

This table should not be used unless the length of the crest is at least 3 or 4 times the depth of water passing over the weir, for if this is not the case, there will be serious errors caused by end contractions.

Inches	0	ł	1	ŧ	ł	ŧ	ŧ	ł
0		.01	.05	.09	.14	.20	.26	.33
1	.40	.47	.55	.65	.74	.83	.93	1.03
2	1.14	1.24	1.36	1.47	1.59	1.71	1.83	1.96
3	2.09	2.23	2.36	2.50	2.68	2.78	2.92	3.07
4	3.22	3.37	3.52	3.68	3.83	3.99	4.16	4.32
1 2 3 4 5 6 7 8 9	4.50	4.67	4.84	5.01	5.18	5.36	5.54	5.72
6	5.90	6.09	6.28	6.47	6.65	6.85	7.05	7.25
7	7.44	7.64	7.84	8.05	8.25	8.45	8.66	8.86
8	9.10	9.31	9.52	9.74	9,96	10.18	10.40	10.62
9	10.86	11.08	11.31	11.54	11.77	12.00	12.23	12.47
10	12.71	13.95	13.19	13.43	13.67	13.93	14.16	14.42
11	14.67	14.92	15.18	15.43	15.67	15.96	16.20	16.46
12	16.73	16.99	17.26	17.52	17.78	18.05	18.32	18.58
13	18.87	19.14	19.42	19.69	19.97	20.24	20.52	20.80
14	21.09	21.37	21.65	21.94	22.22	22.51	22.79	23.08
15	23.38	23.67	23.97	24.26	24.56	24.86	25.16	25.46
16	25.76	26.06	26.36	26.66	26.97	27.27	27.58	27.89
17	28.20	28.51	28.82	29.14	29.45	29.76	30.08	30.39
18	30.70	31.02	31.34	31.66	31.98	32.31	32.63	32.96
19	33.29	33.61	33.94	34.27	34.60	34.94	35.27	35.60
20	35.94	36.27	36.60	36.94	37.28	37.62	37.96	38.31
21	38.65	39.00	39.34	39.69	40.04	40.39	40.73	41.09
22	41.43	41.78	42.13	42.49	42.84	43.20	43.56	43.92
23	44.28	44.64	45.00	45.38	45.71	46.08	46.43	46.81
24	47.18	47.55	47.91	48.28	48.65	49.02	49.39	49.76

CONVERSION FACTORS.

Cubic Feet Into Gallons:

1 cu. ft. = 1,728 cu. in. =
$$\frac{1,728}{231}$$
 gal. = 7.4805194 gal.

Gallons Into Cubic Feet:

1 United States liquid gal. = 231 cu. in. = $\frac{231}{1,728}$ cu. ft. = .133680555 cu. ft.

Feet per Second Into Miles per Hour:

1 ft. per sec. = 3,600 ft. per hr. =
$$\frac{3,600}{5,280}$$
, or $\frac{15}{22}$ miles per hour.

Miles per Hour Into Feet per Second:

1 mi. per hr. = 5,280 ft. per hr. =
$$\frac{5,280}{3,600}$$
, or $\frac{22}{15}$ ft. per sec.

Second-Feet per Day Into Gallons:

1 second-foot, or 7.4805194 gal. per sec. for 1 day, or 86,400 sec. = 646,316.87616 gal.

Millions of Gallons Into Second-Feet per Day:

1,000,000 gal. per 24 hr. = $\frac{231,000,000}{1,728 \times 86,400}$ cu. ft. per sec., or 1.5472286 second-feet.

Second-Feet per Day Into Acre-Feet:

1 second-foot flow for 1 day = 86,400 cu. ft. = $\frac{86,400}{43,500}$, or 1.983471 acre-feet.

Acre-Feet Into Second-Feet Flow for 24 Hours:

One acre-foot each 24 hr. = 43,560 cu. ft. each 86,400 sec. $\frac{43,560}{86,400}$, or $\frac{121}{240}$ second-foot flow for 24 hr.

Acre-Feet Into Gallons:

1 acre-foot = 43,560 cu. ft. =
$$\frac{43,560 \times 1,728}{231}$$
, or $\frac{75,271,680}{231}$, or 325,851.428 gal.

Millions of Gallons Into Acre-Feet:

1,000,000 United States liquid gal., or 231,000,000 cu. in. = 133,680.555 cu. ft., or $\frac{133,680}{43.560} = 3.0688832$ acre-feet.

Second-Feet Into Minute Gallons:

FACTORS: 1 cu. ft. contains 1,728 cu. in.; 1 gal. has a capacity of 231 cu. in.; 1 second-foot equals $[(1,728 \div 231) \times 60]$ gal. per min., or 448.831164 minutegallons.

Minute-Gallons Into Second-Feet:

FACTORS: 1 gal. contains 231 cu. in.; 1 cu. ft. contains 1,728 cu. in.; 1 gal. per min. equals $[(231 \div 1,728) \div 60]$ second-feet, or .0022280092 second-foot.

FLOW OF WATER IN OPEN CHANNELS.

Ditches. - In the case of hydraulic mining and irrigation, water is usually conveyed through ditches. The ditch line should be carefully surveyed and all brush and trees removed, and the underbrush cut away and burned, before beginning to excavate the ditch.

The following letters will be used in the formulas for determining the

various factors relating to ditches:

h = difference in level between ends of canal or ditch, or between two points under consideration;

== horizontal length of portion of canal or ditch under consideration:

 $s = \text{slope} = \text{ratio } \frac{n}{l} = \sin \text{ of slope};$

a = area of water cross-section in square feet:

p = wet perimeter = portion of outline of cross-section of stream in contact with channel, in feet;

 $r = \text{hydraulic radius, or hydraulic mean depth} = \text{ratio} \frac{a}{-}$

c' = coefficient, depending on nature of surface of the ditch:

c = coefficient depending on nature of surface of ditch, as determined by Kutter's formula;

v = mean velocity of flow in feet per second; v' = surface velocity of a stream;

 $v_b = \text{bottom velocity of a stream}$:

x =bottom or one side of a section, the form of which is half a regular hexagon, in feet;

Q = quantity of water flowing, in cubic feet per second; n = coefficient of roughness in Kutter's formula.

The form of ditch and its grade will depend largely on the amount of water to be conveyed and the character of the soil in the section under consideration. As a general rule, the average flow of water in a ditch should not be less than 2 ft. per second, and under most circumstances should not exceed 4 ft., though in rare cases where the formation is suitable, mean velocities of 5 ft. per second are employed. Sand will deposit from a current flowing at the rate of 11 ft. per second, and if the current does not have a velocity of at least 2 ft. per second, vegetation is liable to block the ditch line.

Safe Bottom Velocity.—The bottom velocity of a stream may be obtained from the average velocity by the following formula: $v_b = v - 10.87 \, \text{y/rs}$. The following table gives values of safe bottom and mean velocities, cor-

responding with certain materials, as given by Ganguillet and Kutter:

Material of Channel.	Safe Bottom Velocity v. Feet per Second.	Mean Velocity v. Feet per Second.
oft brown earth	.249	.328
oft loam	.499	.656
ravel	1.000	1.312
ravel	1.998	2.625
ennies	2.999	3.938
roken stone, flint	4.003	5.579
onglomerate, soft slate	4.988	6.564
ratified rock	6.006	8.204
lard rock	10.009	13.127

Resistance of Soils to Erosion by Water.—W. A. Burr, "Engineering News," February 8, 1894, gives a diagram showing the resistance of various soils to erosion by water. The following values have been selected from Mr. Burr's work for different kinds of soil:

Pure sand resists erosion by flow of	
Sandy soil, 15% clay	1.20 ft. per sec.
Sandy loam, 40% clay	1.80 ft. per sec.
Loamy soil, 65% clay	3.00 ft. per sec.
Clay loam, 85% clay	4.80 ft. per sec.
Agricultural clay, 95% clay	6.20 ft. per sec.
Clay	7.35 ft. per sec.

Carrying Capacity of Ditches.—Ditches should never be run full, but should be constructed large enough so that they will carry the desired amount of water when from \(\frac{1}{2} \) to \(\frac{1}{2} \) full. For any given cross-section, the greatest flow will be attained when the hydraulic radius or hydraulic mean depth is equal to one-half of the actual depth of the channel. The cross-section of a ditch or conduit that has the greatest possible carrying capacity is a half circle, and the nearest practical approach to this is a half hexagon. Knowing the cross-section of a ditch, its dimensions may be found by the formula:

$$x = \sqrt{\frac{2a}{2.598}}.$$

As the obtuse angle between the side and bottom of the ditch is 120°, the form can be easily laid off. The carrying capacity of ditches generally increases after they have been in use some time, as the ditch becomes lined with a fine scum that closes the pores in the soil and prevents leakage. This

may increase the amount to as much as 10%.

Grade.—The grade of the ditch must be sufficient to create the desired velocity of flow, and depends largely on the character of the material composing the surfaces of the ditch. If the surface is smooth, as, for instance, where the ditch is cut through clay or is lined with masonry, the grade can be considerably less than where the surface is rough, or when cut through coarse gravel or when lined with rough stone. In mountainous countries, where the ground is hard, deep narrow ditches with steep grades are generally preferred to larger channels with gentle slopes, as the cost of excavation is considerably less; but steep grades and narrow ditches are suitable only when the banks can resist the rapid flow. In California, grades of from 16 to 20 ft. per mile are used, and 10 ft. per mile is quite common. Water channels of a uniform cross-section should have a uniform grade, otherwise, the flow will be checked in places, which will result in deposits of sand or silt in some portions of the ditch, which are liable to cause the banks to be overflowed and the ditch to be ultimately destroyed. In designing any given ditch, the grade is generally assumed to correspond to the formation of the country and the velocity figured from the grade. In case v is found to be so great that it would cut the banks, it will be necessary either to reduce the grade or to change the form of the ditch so as to reduce the velocity.

Ditch banks, when possible, should be composed of solid material, but frequently it is necessary to use excavated material. Where this is the case, care must be taken to see that the material is so placed as to avoid settling

and cracking as much as possible. All stumps, roots, etc. should be separated from the material to be used for embankments. If artificial banks are necessary, it is best to build them of masonry, provided the expense is not too great; or, the water may be carried across depressions in pipes or flumes. When the character of the material through which the ditch is constructed is not sufficiently firm to resist the desired current velocity, it becomes necessary to line the ditch. In some locations the ditches are simply smoothed on the inside and lined with from \$\frac{1}{2}\$ in. to 1 in. of cement mortar, made up of Portland cement and sharp sand. In other cases they are lined with dry stonework laid up in order and carefully bonded together. Sometimes the stonework is pointed with cement or mortar on the inside, so as to present a more uniform surface to the flow. In other cases, the sides are simply revetted with stone.

Influence of Depth on Ditch.—The depth of the flow in a ditch has considerable influence on the scouring or eroding of the bottom and the barks, owing to the fact that a much greater average velocity can be attained in a deep stream than in a shallow stream, without causing an excessive velocity of the water in contact with the wet perimeter. For this reason, in cases where banks will stand it, it is best to use narrow deep ditches rather than wide flat ditches, though each location has to be treated in accordance with

its own special conditions, and no general rule can be laid down.

Measuring the Flow of Water in Channels.—The laws for the resistance to the flow may be expressed by the relation (see page 142 for significance of letters):

$$ha = c' l p v^2$$
; or, $v = \sqrt{\frac{h}{c' l} \times \frac{a}{p}} = \sqrt{\frac{l}{c'} \times s \times r}$.

If
$$c = \sqrt{\frac{l}{c'}}$$
, the formula becomes $v = c \sqrt{rs}$.

The coefficient c is usually found by means of Kutter's formula, one form of which is as follows:

$$c = \frac{23 + \frac{1}{n} + \frac{.00155}{8}}{.5521 + \left(23 + \frac{.00155}{8}\right) - \frac{n}{\sqrt{r}}}.$$

The values for n, the coefficient of roughness, under various conditions, are as follows:

Character of Channel.	Value of n.
Clean, well-planed timber	.009
Clean, smooth, glazed iron, and stoneware pipes	.010
smooth, cast-iron pipe	.011
sewers, well laid and thoroughly flushed	.012
usual conditions Dressed masonry and well-laid brickwork	.013
Good rubble masonry and ordinary rough or fouled brickwork	.015 .017
Coarse rubble masonry and firm, compact gravel	.020 .0225
Rivers and canals in moderately good order and perfectly free from stones and weeds	.025
Rivers and canals in rather bad condition and somewhat obstructed by stones and weeds	.030
Rivers and canals in bad condition, overgrown with vegeta-	.030
tion and strewn with stones and other detritus, according to condition	.035 to .050

As it is quite difficult to obtain the value of c by Kutter's formula, the following three approximate formulas for v are given:

For canals with earthen banks, $v = \sqrt{\frac{100,000 r^2 s}{9 r + 35}}$. If the ditch is lined with dry stonework, $v = \sqrt{\frac{100,000 r^2 s}{8 r + 15}}$. If the ditch is lined with rubble masonry, $v = \sqrt{\frac{700,000 r^2 s}{7.3 r + 6}}$.

To find the quantity Q of water flowing through any channel in a given time, multiply the velocity by the area, or Q = av.

Flow in Brooks and Rivers.—When a stream is so large that it becomes impracticable to employ a weir for measuring its flow, fairly accurate results may be arrived at by determining the velocity of the current at various points in a carefully surveyed cross-section of the stream, thus determining both r and a. The greatest velocity of current occurs at a point some distance below the surface, in the deepest part of the channel. When determining the current velocities in the different portions of a stream, it is frequently advantageous to divide the stream into divisions. This may be accomplished by stretching a wire across and tying strings or rags about the wire at various points. The mean velocity of the current between these points can be determined by current meters, or by floats. The points for observation should be chosen where the channel is comparatively straight and the current uniform. Surface floats may be used, in which case the mean velocity of the point where the float is used may be found as follows:

and the current uniform. Surface floats may be used, in which case the mean velocity of the point where the float is used may be found as follows: If v' equals the observed velocity, then the mean velocity will be $v = .9 \, v'$. By taking observations of the velocity of the current in each section of a stream, the amount of water flowing may be determined for each separate section. The total amount of water flowing in the stream will be the sum of the amounts in each section. The average velocity of the entire stream may be found by dividing the total amount of water flowing by total area of the cross-section of the stream. The correction necessary to reduce surface velocity to mean velocity may be made as follows: Measure off $\frac{1}{10}$ of the ordinary distance, and figure the time as though for the full distance. For instance, if only 90 ft. were employed, the time would be taken and the problem figured as though it were 100 ft., on account of the fact that the

mean velocity is only to of the surface velocity.

FLUMES.

Flumes are used for conveying water when a ditch line would be abnormally long, or when the material to be excavated is very hard. They may be constructed of timber or of metal, but metal flumes are comparatively rare, as piping can be used instead. The line of the proposed flume should be carefully cleared of all standing timber, and the brush burned for at least 20 ft. each side of the flume line to prevent danger from fire. The life of an ordinary flume, which is supported on or constructed of timber, is always short, varying, as a rule, from 10 to 20 years, depending on whether the flume is allowed to run dry a portion of the year or is always full of water, the care with which it was originally constructed, and the attention paid to repairs.

Grade of Flumes.—Flumes are usually set on a much steeper grade than is possible in ditches, the grade frequently being as much as 25 to 30 ft. per mile, and in special cases even more. The result of this is that the carrying capacity of flumes is much greater than that of ditches of the same size.

The form of flume depends largely on the material of which it is constructed.

The form of flume depends largely on the material of which it is constructed.

Metal flumes may have a semicircular form, while wooden flumes are either rectangular or V-shaped. The former is used almost exclusively for conveying water, and the latter quite extensively for fluming timber or cord wood from the mountains to the shipping point in the valley.

Timber flumes should be so constructed that the water will meet with but

Timber flumes should be so constructed that the water will meet with but small resistance, and the bottom and side should be enclosed in a frame of timbers so braced or secured that there is no possible chance of the sides spreading or lifting from the bottom, and thus cause leakage. As a rule, all mortised and tenoned joints should be avoided in flume construction.

Fig. 12 shows a timber flume in which no joints are cut, the bottoms of the posts being kept in place by stringers spiked on the sills, and the tops tied together by pieces boiled on. Fig. 13 shows a construction in which the post are let into the sills and supported by diagonal braces. The ties across the top of the posts are also notched to receive the upper ends of the posts. Asi

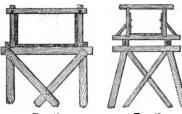


Fig. 12.

Fig. 13.

rule, in such a construction these ties are only placed on every third or fourth frame, the diagonal braces being depended on to hold the other posts in place. The joints between the planking joints between the planking may be battened on the inside with strips of \(\frac{1}{2}'' \) lumber, \(4 \to 5 \) in. wide, or the edges of the planking may be dressed and painted before they are put together, so as to form a tight joint.

Connection With Diches.

Where flumes connect with ditches or dams, the posts

for several boxes should be made longer, so that they may receive another sideboard to prevent the water from splashing over the sides. The flume should also be widened out or flared, both at its entry and discharge ends. Where the flume passes through a bank of earth, an outer siding may be nailed on the outside of the posts, to protect the flume from rotting.

Trestles.—Where flumes are carried on trestles, the individual frames supporting the flume are usually placed on heavy stringers, which in turn are supported upon trestle bents from 12 to 16 ft. apart, the frames supporting

the flume being placed about 4 ft. apart.

Curves.—Where flumes are laid around curves, the outer edge of the flume should be elevated so as to prevent splashing and to cause the flowing water to have a uniform depth across the width of the flume. It is impossible to give any definite rule as to the amount that the outer edge of the flume should be raised, but this is usually accomplished by judging the amount when the flume is first constructed, and correcting this by wedging up after the water is flowing. The individual boxes of the flume may have to be cut into 2 or 3 portions on curves, and at times the side planks are sawed

partially through, so as to enable them to be bent to the desired curve.

Waste gates should be placed every half mile, to empty the flume for repairs, or in case of accident. They are also useful for flushing snow out of a flume. In snow regions, flumes are frequently protected by sheds over

their exposed portions.

Flow of Water Through Flumes.—As smooth wooden surfaces offer considerably less resistance to the flow of water than earth or stone canals, the coefficients must necessarily be somewhat reduced, and the following formula is useful in giving the flow of water through flumes:

$$v = \sqrt{\frac{100,000 \ r^2 \ s}{6.6 \ r + 0.46}}.$$

That flumes may have their full carrying capacity, they have to be of sufficient length to get the water in motion, or, as it is technically expressed, "to put the water in train." It is largely on this account that flumes have to be made of a larger cross-section at both the entrance and the exit. cold countries it may be best to construct the flume narrower than it is deep, as in cold weather the ice in the narrow flume freezes a crust entirely across the surface, thus protecting the water from further action of the elements and frequently prolonging the flow through the flume for several weeks, while wide shallow flumes will not freeze on the surface so quickly, but will freeze in from the bottom and sides until they are practically a solid mass of ice. When a finne is laid on the ground along a bank, it should be laid as close to the bank as possible, so as to protect it from snow or landslides, and so that in the winter the snow will drift in under and behind it, thus preventing the circulation of the air about the finme. This will protect the flume, and may prolong the flow for some time after cold weather sets in.

TUNNELS.

Tunnels are sometimes used for conveying water, in connection with flume or ditch lines. Where a tunnel is unlined, it is best to give the roof the shape of the Gothic arch, owing to the fact that this stands better and resists scaling to a greater extent than the round arch, which usually scales off until it has the form of the Gothic arch. If tunnels are to be used as water conduits, without lining, care should be taken to make the inside of the tunnel as smooth as possible. In some cases, in order to increase the carrying capacity of the tunnel, they have been lined with wooden-stave pipe, backed with concrete, the pipe requiring no metal bands, but depending on the concrete to keep it in place. When such linings are employed, it is not practicable to have them exposed to the alternate action of the water and the atmosphere, hence the tunnel should be kept continually full of water. To accomplish this, the tunnel may be dropped below the grade of the ditch or flume line, so that it is always under a slight hydrostatic pressure, and even if the water were turned off from the line, the tunnel would remain full of water, the same as an inverted siphon. Sometimes tunnels are lined with cement, being given either a circular or oval form, or they may have a flat bottom, with flat sides and an arched roof. The cement may be placed directly on the country rock composing the walls of the tunnel, or the tunnel may be lined with brick or stone, and then cemented on the inside.

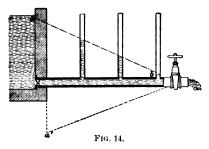
Flow Through Tunnels.—The flow of water through tunnels, when they are only partially filled, is calculated by the formulas for flow in open channels, while in the case of lined tunnels that are run full, the flow is calculated by

formulas for calculating the flow through pipes.

FLOW THROUGH PIPES.

Hydraulic Gradient.—If a pipe of uniform cross-section be connected with a reservoir, and water allowed to discharge through its open end, it has been found that the pressure on the pipe at any point is equal to the vertical distance from the center of the pipe at that point to an imaginary line, called the hydraulic gradient or hydraulic grade line. This is a line drawn from a point slightly below the

point slightly below the surface of the water in the reservoir to the outlet of the pipe, as ab, Fig. 14. The distance from the surface of the water to the point a is equal to the head lost in overcoming the friction at the entrance to the pipe, and is rarely over 1 ft. If the pipe were laid along the line ab, it would carry exactly the same amount of water as when laid horizontally, as shown, but there would be practically no pressure tending to burst the pipe at any point along this line.



zontally, as shown, but there would be practically no pressure tending to burst the pipe at any point along this line; while if it were laid along the line from the point a' (the reservoir being made deeper), it would still deliver exactly the same amount of water, but that a pipe may have a maximum discharge, no point in the line must rise above the hydraulic gradient, and it makes no difference in the discharge how far below the gradient it may fall.

In Fig. 15, the pipe rises above the hydraulic gradient ac, and in this case a new hydraulic gradient ab would have to be established, and the flow calculated for this head, the pipe bc simply acting to carry off the water delivered to it at b. If the upper side of the pipe were open at the point b, the water would have no tendency to escape, but, on the contrary, air would probably enter, and the pipe flow only partially full from b to c.

Flow in Pipes.—Darcy, a French engineer, made a series of experiments on different diameters of cast-iron pipe, with different degrees of internal

roughness, from which he calculated a series of formulas. The following are some of these formulas, as arranged by Mr. E. Sherman Gould, C. E., E. N one of the most experienced hydraulic engineers in America. Darcy foun

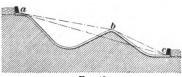


Fig. 15.

that the character of the insid surface of the pipe played very important part in its di charge, and he deduced formula and determined series of coefficients for it, but Mr. Gould calls attention to the fact that the coefficients for pipes from 8" to 48" in diameter practically cancel the numerical factor employed in

numerical factor employed in Darcy's formula, and that a slightly different factor applies to pipes from 3 to 8 in., so that we may have the following simple formulas, in which the factors given apply: Q = amount of water in cubic feet per second; Q = U. S. gallons per second; Q = diameter of pipe in feet; Q = diameter of pipe in inches; Q = diameter of pipe in inches;

h = head per 1,000 ft.; V = velocity in feet per second.

Pipes above 8 in. in diameter, rough inside surface,

$$Q = \sqrt{D^5 h} = D^2 \sqrt{D h}; \quad V = 1.27 \sqrt{D h}.$$

For diameter in inches.

 $Q = d^2 \sqrt{d h}$ Pipes between 3 and 8 in. in diameter, rough inside surface.

$$Q = 0.89 \sqrt{D^5 h} = 0.89 D^2 \sqrt{D h}; \quad V = 1.13 \sqrt{D h}.$$

Large pipes, smooth inside surface,

$$Q = 1.4\sqrt{D^5}\,\hat{h} = 1.4\,D^2\sqrt{D\,\hat{h}}; \ V = 1.78\sqrt{D\,\hat{h}}.$$

Small pipes, smooth inside surface,

$$Q = 0.89 \sqrt{2 D^6 h} = 1.25 D^2 \sqrt{D h}; V = 1.6 \sqrt{D h}.$$

As a rule, it is best to calculate any pipe line by the formula for pipes having a rough internal surface, for if this is not done the results are liable to be disappointing, owing to the fact that all pipes become more or less rough with use.

Eytelwein's Formula for the Delivery of Water in Pipes:

D = diameter of pipe in inches;

H = head of water in feet:

L =length of pipe in feet; W =cubic feet of water discharged per minute

$$W = 4.71 \sqrt{\frac{D^5 H}{L}}. \qquad D = .538 \sqrt[5]{\frac{L \times \overline{W^2}}{H}}$$

Hawksley's Formula:

G =number of gallons delivered per hour;

L =length of pipe in yards; H =head of water in feet;

D = diameter of pipe in inches.

$$D = \frac{1}{18} \sqrt[5]{\frac{G}{H}}, \quad G = \sqrt{\frac{(15\overline{D})^5H}{L}}$$

Neville's General Formula:

v == velocity in feet per second;

r = hydraulic mean depth in feet:

s =sine of inclination, or total fall divided by total length.

$$v = 140 \sqrt{rs} - 11 t^3 rs.$$

In cylindrical pipes, v multiplied by $47.124 d^2$ gives the discharge per minute in cubic feet, or v multiplied by $293.7286 d^2$ gives the discharge per minute in gallons, d being the diameter of the pipe in feet.

COMPARISON OF FORMULAS.

R= mean hydraulic depth in feet = area + wet perimeter = $\frac{d}{4}$ for circular section of pipe;

 $S = \text{sine of slope} = \frac{H}{L};$

 $egin{array}{ll} v &= ext{velocity in feet per second;} \ d &= ext{diameter of pipe in feet;} \ L &= ext{length of pipe in feet;} \ H &= ext{head of water in feet.} \end{array}$

Prony, $v = 97.05 \sqrt{RS} - .08$; or, $v = 99.88 \sqrt{RS} - .154$.

 $v = 50\sqrt{\frac{dH}{L + 50d}}$ Eytelwein,

 $v = 108 \sqrt{RS} - .13$ Eytelwein.

 $v = 48\sqrt{\frac{dH}{L + 54d}}$ Hawksley,

v = 1401/RS - 111 / RSNeville.

Darcy, $v = C\sqrt{RS}$; for value of C, see following Table.

Diameter of pipe (inches) Value of C	1	1	2	3	4	5	6	7	8
	65	80	93	99	102	103	105	106	107
Diameter of pipe (inches) Value of C	9	10	12	14	16	18	20	22	24
	108	109	109.5	110	110.5	110.7	111	111.5	111.5

Maximum value of C for very large pipes, 113.3.

 $v = C \sqrt{R S}$ Kutter,

 $C = \frac{181 + \frac{.00281}{S}}{1 + \frac{.026}{\sqrt{d}} \left(41.6 + \frac{.00281}{S}\right)}.$ where

 $h = \frac{L}{r} \left(.0036 + \frac{.0043}{1/\sqrt{r}} \right) \frac{v^2}{2 J}$ Weisbach.

where h = head necessary to overcome the friction in a pipe; r = the meanradius of the pipe in feet; and g = gravity = 32.2.

 $h = \frac{.02 L}{d} \left(1 + \frac{1}{12 d} \right) \frac{v^2}{2 a}$ Darcy.

Siphons.—When any part of the pipe line rises above the source of supply, such a line is called a siphon. If this rise is greater than the height of the water barometer (34 ft. at sea level), water will not flow through the siphon. The flow through the siphon will be the same as that through any pipe line so long as there is no accumulation of air at the highest point of the line; but such an accumulation will decrease or entirely stop the flow. All siphons should be provided at their highest points with valves for discharging the air and introducing water to fill the siphon, and it is usually best to trap the lower end of the pipe so that air cannot enter it, and to enlarge the upper end so as to reduce the loss of the stream in entering. For a siphon to work well, the fall between the intake and the discharge end should be considerable. If the rise amounts to much. considerable, if the rise amounts to much.

TABLE SHOWING THE ACTUAL AMOUNT, OR 80% OF THE THEORETICAL FLOW IN PIPES FROM 1 IN. TO 30 IN. DIAMETER. (Supplement to "Industry," No. 45, April, 1892.)

		30	4 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6
		24	2.5 65.2 2.5
		18	1,267 1,267 1,267 1,267 1,267 1,267 1,267 1,267 1,267 1,273
		15	793 1174 1174 1174 1174 1174 1174 1174 117
		12	653 653 653 653 653 653 653 653 653 653
		=	858 858 858 858 858 858 858 858 858 858
	wi.	10	279 4155 4156 4156 4157 4158 4
	Inches	6	4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
	Pipes.	8	1111 156 234 286 286 284 286 284 286 284 286 284 286 284 286 284 286 284 286 284 286 284 286 284 286 284 286 284 286 284 286 284 284 284 284 284 284 284 284 284 284
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	ide Di	4	88288888888888888888888888888888888888
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		2 24	44.2 8.5 11.1 9.8 11.1 11
1		113	44.2 50.5 50.5 50.5 50.5 50.5 50.5 50.5 50
		7	0.88.4.6.6.6.7.7.1147.012.8.8.8.8.116.8.6.8.4.8.8.8.9.9.0.0.0.0.4.0.4.0.7.7.147.012.8.8.8.9.7.7.0.0.0.0.7.0.0.8.4.0.0.0.0.0.0.7.0.0.8.4.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0
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		nko	R88554585545845858658375594868
	ll or	Slope.	88888888888888888888888888888888888888
-	F.	\mathbf{z}	112846612891128486128466 12846612846

The quantities above are American gallons per minute. For cubic feet, divide by 7.5.

LOSS OF HEAD IN PIPE BY FRICTION

In each 100 ft. in length of different diameters, when discharging the following quantities of water per minute, as given by Pelton Water Wheel Co.

INSIDE DIAMETER OF PIPE. INCHES.

1		1		2	l	8			5		6	
Velocity. Ft. per Sec.	Lons of Head, Ft.	Cu. Ft. per Min.	Loss of Head. Ft.	Cu. Ft. per Min.	Loss of Head. Ft.	Ca. Ft. per Min.	Loss of Head. Ft.	Cu. Ft. per Min.	Loss of Head. Ft.	Cu. Pt. per Min.	Loss of Head. Ft.	Ca. Ft. per Min.
2.0	2.37	.65	1.185	2.62	.791	5.89	.593	10.4	.474	16.3	.395	23.5
2.2	2.80	.73	1.404	2.88	.936	6.48	.702	11.5	.561	18.0	.468	25.9
2.4	3.27	.79	1.639	8.14	1.098	7.07	.819	12.5	.650	19.6	.547	28.2
2.6	8.78	.86	1.891	3.40	1.260	7.65	.945	13.6	.757	21.3	.631	30.6
2.8	4.32	.92	2.160	3.66	1.440	8,24	1.080	14.6	.864	22.9	.720	82.9
3.0	4.89	.99	2.440	3.92	1.620	8.88	1.220	15.7	.978	24.5	.815	35.8
3.2	5.47	1.06	2.730	4.18	1.820	9,42	1.370	16.7	1.098	26.2	.915	37.7
3.4	6.09	1.12	3.050	4.45	2.040	10.00	1.520	17.8	1.220	27.8	1.021	40.0
3.6	6.76	1.19	3,380	4.71	2.260	10.60	1.690	18.8	1.350	29.4	1.131	42.4
3.8	7.48	1.26	8.740	4.97	2.490	11.20	1.870	19.9	1.490	31.0	1.250	44.7
4.0	8.20	1.32	4.100	5.23	2.730	11,80	2.060	20.9	1.640	32.7	1.370	47.1
4.2	8.97	1.39	4.490	5.49	2,980	12,30	2.240	22.0	1.790	84.3	1.490	49.5
4.4	9.77	1.45	4,890	5.76	3.250	12.90	2.430	23.0	1.950	36.0	1.620	51.8
4.6	10.60	1.52	5.300	6.02	3,530	13.50	2.649	24.0	2,110	87.6	1.760	54.1
4.8	11.45	1.58	5.720	6.28	3.810	14.10	2.850	25.1	2.270	89.2	1,900	56.5
5.0	12.33	1.65	6.170	6.54	4.110	14.70	3.080	26.2	2.460	40.9	2.050	58.9
5.2	13.24	1.72	6.620	6.80	4.410	15.30	3.310	27.2	2.650	42.5	2.210	61.2
5.4	14.20	1.78	7.100	7.06	4.730	15.9∪	8,550	28.2	2.840	44.2	2,370	63.6
5.6	15.16	1.85	7.580	7.32	5.060	16.50	3.790	29.3	3.030	45.8	2,530	65.9
5.8	16.17	1.91	8,090	7.58	5.400	17,10	4.040	80.8	3.240	47.4	2.700	68.8
6.0	17.23	1.98	8,610	7.85	5.740	17.70	4.310	31.4	8.450	49.1	2.870	70.7
7.0	22.89	2.31	11.450	9.16	7.620	20.60	5.720	36.6	4.570	57.2	3,810	82.4

INSIDE DIAMETER OF PIPE. INCHES.

ا نو .		7		8		9	10	ο.	1	1	1	2
Velocity. Ft. per Sec.	Loss of Head. Ft.	Cu. Ft. per Min.										
2.0	.338	32.0	.296	41.9	.264	53.0	.237	65.4	.216	79.2	.198	94.2
2.2	.401	35.8	.351	46.1	.312	58.3	.281	72.0	.255	87.1	.234	103.0
2.4	.468	38.5	.410	50.2	.365	63.6	.327	78.5	.297	95.0	.273	113.0
2.6	.540	41.7	.473	54.4	.420	68.9	.378	85.1	.344	103.0	.315	122.0
2.8	.617	44.9	.540	58.6	.480	74.2	.432	91.6	.392	111.0	.360	132.0
3.0	.698	48.1	.611	62.8	.544	79.5	.488	98.2	444	119.0	.407	141.0
3.2	.785	51.3	.686	67.0	.609	84.8	.549	105.0	.499	127.0	.457	151.0
3.4	.875	54.5	.765	71.2	.680	90,1	.612	111.0	.557	134.0	.510	160.0
3.6	.969	57.7	.848	75.4	.755	95.4	.679	118.0	.617	142.0	.566	169,0
3.8	1.070	60.9	.936	79.6	.831	101.0	.749	124.0	.680	150.0	.624	179.0
4.0	1.175	64.1	1.027	83.7	.913	106.0	.822	131.0	.747	158.0	.685	188.0
4.2	1.280	67.3	1.122	87.9	.998	111.0	.897	137.0	.816	166.0	.749	198.0
4.4	1.390	70.5	1.220	92.1	1,086	116.0	.977	144.0	.888	174.0	.815	207.0
4.6	1.510	73.7	1.320	96.3	1.177	122.0	1.059	150.0	.963	182.0	.883	217.0
4.8	1.630	76.9	1,430	100.0	1.270	127.0	1.145	157.0	1.040	190.0	.954	226.0
5.0	1.760	80.2	1.540	105.0	1.370	132.0	1.230	163.0	1.122	198.0	1.028	235.0
5.2	1.890	83,3	1.650	109.0	1.470	138.0	1.320	170.0	1.200	206.0	1,104	245.0
5.4	2.030	86.6	1.770	113.0	1.570	143.0	1.410	177.0	1.280	214.0	1.183	254.0
5.6	2.170	89.8	1.890	117.0	1.680	148.0	1.510	183.0	1.370	222.0	1.260	264.0
5.8	2,310	98.0	2.010	121.0	1.800	154.0	1.610	190.0	1.460	229.0	1.340	273.0
6.0	2.460	96.2	2.150	125.0	1.920	159.0	1.710	196.0	1,560	237.0	1.430	283.0
7.0	3.260	112.0	2.850	146.0	2.520	185.0	2.280	229.0	2.070	277.0	1.910	330.0

Example.—Have 200 ft. head and 600 ft. of 11" pipe, carrying 119 cu. ft. of water per minute. To find effective head: In right-hand column, under 11" pipe, find 119 cu. ft. Opposite this will be found the coefficient of friction for this amount of water, which is .444. Multiply this by the number of hundred feet of pipe, which is 6, and you will have 2.66 ft., which is the loss of head. Therefore, the effective head is 200-2.66=197.34.

LOSS OF HEAD IN PIPE BY FRICTION

In each 100 ft. in length of different diameters, when discharging the follo \mathbf{w} -ing quantities of water per minute, as given by Pelton Water Wheel Co.

INSIDE DIAMETER OF PIPE. INCHES.

÷	1:	3	1	4		15	1	6	1	8	2	0
Ft. per Sec.	Loss of Head. Ft.	Cu. Ft. per Min.	Loss of Head, Ft.	Cu. Ft.								
.0	.183	110	.169	128	.158	147	.147	167	.132	212	.119	263
.3	.216	121	.200	141	.187	162	.175	184	.156	233	.140	28
.4	.252	133	.234	154	.218	176	.205	201	.182	254	.164	31
.6	.290	144	.270	167	.252	191	.236	218	.210	275	.189	34
.8	.332	156	.308	179	.288	206	.270	234	.240	297	.216	36
3.0	.375	166	.349	192	.325	221	.306	251	.271	318	.245	39
3.2	.422	177	.392	205	.366	235	.343	268	.305	339	.275	41
3.4 3.6	.471	188	.438	218	.408	250	.383	284	.339	360	.306	44
.6	.522	199	.485	231	.452	265	.425	301	.377	382	.339	47
.8	.576	210	.535	243	.499	280	.468 .513	318	.416	403	.374	49
.0	.632	221	.587	256	.548	294	.513	335	.456	424	.410	52
.2	.691	232	.641	269	.598	309	.561	352	.499	445	.449	55
.4	.751	243	.698	282	.651	324	.611	368	.542	466	.488	570
4.6 4.8 5.0 5.2	.815	254	.757	295	.707	339	.662	385	.588	488	.529	602
.8	.881	265	.818	308	.763	353	.715	402	.636	509	.572	621
.0	.949	276	.881	321	.822	368	.770	419	.685	530	.617	654
.2	1.020	287	.947	333	.888	383	.828	485	.736	551	.662	680
.4	1.092	298	1.014	346	.947	397	.888	452	.788	572	.710	707
5.6 5.8	1.167	309	1.083	359	1.011	412	.949	469	.843	594	.758	733
5.8	1.245	321	1.155	372	1.078	427	1.011	486	.899	615	.809	756
6.0 7.0	1.325 1.750	332 387	1.229	385 449	1.148 1.520	442 515	1.076	502 586	.957 1,270	636 742	.861 1.143	785 916

INSIDE DIAMETER OF PIPE. INCHES.

	2	2	2	4		26	2	8	3	30	1	36
Velocity. Ft. per Sec.	Loss of Head. Ft.	Cu. Ft. per Min.	Loss of Head, Ft.	Cu. Ft. per Min.	Loss of Head, Ft.	Cu. Ft. per Min.	Loss of Head. Ft.	Cu. Ft. per Min.	Loss of Head. Ft.	Cu. Ft. per Min.	Loss of Head. Ft.	Cu. Ft.
2.0	.108	316	,098	377	.091	442	.084	513	.079	589	.066	84
2.2	.127	348	.116	414	.108	486	.099	564	.093	648	.078	93
2.4	.149	380	.136	452	.126	531	.116	616	.109	707	.091	1,01
2.6	:171	412	.157	490	.145	575	.134	667	.126	766	.104	1,10
2.8	.195	443	.180	528	.165	619	.153	718	.144	824	.119	1,18
3.0	.222	475	.204	565	.188	663	.174	770	.163	883	.135	1,27
3.2	.249	507	,229	603	.211	708	.195	821	.182	942	.152	1.35
3.4	.278	538	.255	641	.235	752	,218	872	,204	1,001	.169	1.44
3.6	.308	570	.283	678	.261	796	1242	923	.226	1.060	.188	1,52
3.8	.340	601	.312	716	.288	840	.267	974	.249	1,119	,207	1,61
4.0	.373	633	.342	754	.315	885	.293	1,026	.273	1.178	,228	1,69
4.2	.408	665	.374	791	.345	929	.320	1.077	,299	1,237	.249	1.78
4.4	.444	697	.407	829	.375	973	.348	1,129	.325	1,296	.271	1.86
4.6	.482	728	.441	867	.407	1,017	.378	1,180	.353	1,355	.294	1.95
4.8	.521	760	.476	905	.440	1,062	.409	1,231	.381	1,414	.318	2,03
5.0	.561	792	.513	942	.474	1,106	.440	1,283	.411	1,472	.342	2,12
5.2	.602	823	.552	980	.510	1,150	.473	1,334	.441	1,531	.368	2,20
5.4	.645	855	.591	1,018	.546	1,194	.507	1,385	.473	1,590	.394	2.29
5.6	.690	- 887	.632	1,055	.583	1,239	.542	1,437	.506	1,649	.421	2.37
5.8	.735	918	.674	1,093	.622	1,283	.578	1,488	.540	1,708	.450	2,46
6.0	.782	950	.717	1,131	.662	1,327	.615	1,539	.574	1,767	.479	2.54
7.0	1.040	1,109	.953	1,319	.879	1,548	.817	1,796	.762	2,061	.636	2,968

The following formula, deduced by William Cox, gives practically the same results as the foregoing table and will be found useful in many instances: $F = \frac{L}{1,000D}(4V^2 + 5V - 2)$, where F = friction head; L = length of pipe in feet; D = diameter of pipe in inches; V = velocity in feet per second.

Friction of Knees and Bends.—This subject has not been investigated sufficiently to enable the engineer to make exact allowance for this factor, but

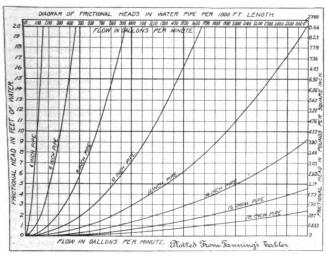
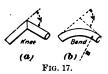


Fig. 16.

the following formulas may be taken as giving close approximate results. It is well to bear in mind that right angles should be avoided whenever possible, and that bends should be made with as large a radius as circumstances will allow.



A = angle of bend or knee with forward line of direction:

V = velocity of water in feet per second;

R = radius of center line of bend;

 $r = \text{radius of bore of pipe (or } \frac{1}{2} \text{ diameter)};$ K = coefficient for angles of knees;

L = coefficient for angles of knees;L = coefficient for curvature of bends;

H == head of water in feet necessary to overcome the friction of the bends, or knees. H == .0155 V^2K .

The value of K is as follows for different angles:

A° == K ==	20° .046	60° ,364	80° .74	.98	100° 1.26	120° 1.86
		 			W 1807 Mar	

For bends, H

$$H = .0155 V^2 \left(\frac{.1}{180}L\right).$$

Values of L with various ratios of the radius of bend to radius of bore:

When	$\frac{r}{R} =$.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
In circular section	L	.131	.138	.158	.206	.294	.44	.66	.98	1.4	2.0
In rectangular		.124	.135	.18	.25	.4	.64	1.01	1.55	2.3	3.2

RESERVOIRS.

Reservoir Site.—In selecting a site for a reservoir, the following points should be observed:

A proper elevation above the point at which the water is required.

The total supply available, including observations as to the rainfall and snowfall.

The formation and character of the ground, with reference to the

amount of absorption and evaporation.

The most desirable formation of ground for a reservoir site is one of com-pact rock, like granite, gneiss, or slate; porous rocks, like sandstones and limestones, are not so desirable. Steep bare slopes are best for the country surrounding a reservoir, as the water escapes from them quickly. The presence of vegetation above the reservoir causes a considerable amount of absorption; but, at the same time, the rainfall is usually greater in a region covered with vegetation than in a barren region, hence the streams have a more uniform flow. A reservoir must be made large enough to hold a supply capable of meeting the maximum demand. The area of a reservoir should be determined, and a table made showing its contents for every foot in dark as that the around the property of preference and the property of the contents of the con in depth, so that the amount of water available can always be known.

DAMS.

Dams are used for retaining water in reservoirs, for diverting streams in placer mining, and for storing debris coming from placer mines in canons or ravines.

Foundations for dams must be solid to prevent settling, and water-tight to prevent leakage under the base of the dam. Whenever possible, the founda-tion should be solid rock. Gravel is better than earth, but when gravel is employed it will be necessary to drive sheet piling under the upper toe of employed it will be necessary to drive sheet plung there are upper too or the dam, to prevent water from seeping through the formation under the dam. Vegetable soil should be avoided, and all porous material, such as sand, gravel, etc. should be stripped off until hard pan or solid rock is reached. In case springs occur in the area covered by the foundation of the dam, it will be necessary to trace them up, and if they originate on the upper side to confine their flow to that side of the dam, so that they will have no tendency to ultimately become passageways for water from the upper face to the lower face of the dam, thus providing holes which may ultimately destroy the entire foundation of the structure.

Wooden Dams.—Wooden dams are constructed of round, sawed, or hewn

logs. The timbers are usually at least 1 ft. square, or, if round, from 18 to 24 in. in diameter. A series of cribs from 8 to 10 ft. square are constructed by building up the logs log-house fashion and securing them together with treenalls. The individual cribs are secured to one another with treenals or by means of bolts. The cribs are usually filled with loose rock to keep them in place, and in many cases are secured to the foundation by means of bolts. A layer of planking on the upper face of the dam makes it water-tight, and if the spillway is over the crest of the dam it will be necessary to plank the top of the cribs, and, in most cases, to provide an apron for the water to fall on. The apron may be set on small cribs, or on timbers projecting from the cribs of the dam itself.

Abutments and Discharge Gates.—Abutments are structures at the ends of a dam. They may be constructed from timber, masonry, or dry stonework. If possible, abutments should have a curved outline, and should be so placed that there is no possibility of the water overflowing them, or getting behind them during floods. If the regular discharge from a dam takes place from the main face, the gates may be arranged in connection with one of be abutments, or by means of a tunnel and culvert through the dam. In DAMS. 155

either case, some structure should be constructed above the outlet so as to prevent driftwood, brush, and other material from stopping the discharge gates are placed at one side of the dam, they are usually arranged outside of the regular abutment, between it and another special abutment, the discharge being through a series of gates into a flume, ditch, or pipe.

Spillweys or Waste Ways.—These are openings provided in a dam for the discharge of water during floods or freshets, or for the discharge of a portion not being used at any time. The spillway may be over the crest of the dam, or, where the topography favors such a construction, the main dam may be of sufficient height to prevent water from ever passing its crest, the spillway being arranged at another outlet over the lower dam. Waste ways, proper, are openings through the dam, and are intended for the discharge of the large quantities of water that come down during freshets or floods. In the case of timber dams, the waste ways are usually surrounded by heavy cribs and have an area of from 40 to 50 sq. ft. each. There are two general forms of construction employed for waste ways. One consists of a comparatively narrow opening in the dam, extending to a considerable depth (8 or

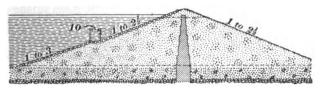


Fig. 18.

10 ft.). Water is allowed to discharge through this during flood time, but when it is desired to stop, the flow planks are placed across the up-stream face of the opening in such a manner as to close it. The opening, which is usually not over 3 or 4 ft. wide, is provided with guides on the upper face of the dam, and between which the planks are slid down, the individual pieces of planking being at least 1 ft. longer than the opening that they are to cover. The other device frequently used consists in providing the waste way, at one side of the regular spillway, with a crest 2 or 3 ft. lower than the regular spillway. The crest of this waste way is composed of heavy timber, and 4 or 5 ft. above there is arranged a parallel timber, the space between the two being closed by what are called flash boards. These are made from pieces of 2" or 3" plank, 6 or 8 in. wide. The planks are placed against both timbers so as to close the space. The individual planks are made long enough so that they extend from 1 to 2 ft. above the upper timber, and through the upper end of each plank is bored a hole through which a piece of rope is passed and a knot tied in the end of the rope. These ropes are secured by staples to the upper timber. When it becomes necessary to open the waste way, men go under with peevies, cant hooks, or pinch bars, and pry up the planks in such a way as to draw the longer end out of contact with the lower timber, when the force of the water will immediately carry the plank down the stream as far as the rope will allow it to go. After the first plank has been loosened, the succeeding ones can be pulled up with comparative ease, and two men can open a 25 or 30 section of waste way in a very few minutes. The ropes keep the plank from being lost, and the opening can be closed again by passing the plank down into the water to one side of the opening and moving them into the current. Some skill is required, both in opening and moving them into the current. Some skill is required, both in opening and moving them

Stone Dams.—Where cement or time is expensive, and suitable rubble stone can be obtained, dams are frequently constructed without the use of mortar. The upper and lower faces of the dam should be of hammer-dressed stone, carefully bonded, and the stones in the lower face of the dam are sometimes anchored by means of bolts. The dam can be made water-sight by means of a skin of planking on the upper face. In case water should ever pass over the crest of such a dam, much of it would settle through the openings in the stone into the interior of the dam, and this would subject the stones in the lower portion of the face to a hydrostatic

pressure, provided an opening was not made for the escape of such water. For this reason, culverts or openings should be made through the lower portion of the dam, to discharge any such water. When such dams as this are constructed, the regular spillway is not placed over the face of the dam,

but at some other point, and usually over a timber dam.

Earth Dams.—Earth dams are used for reservoirs of moderate height. They should be at least 10 ft. wide on top, and a height of more than 60 ft. is unusual. When the material of which the dam is composed is not watertight, as, for instance, gravel, sand, etc., it is sometimes necessary to construct a puddle wall of clay in the center of the regular dam. This consists of a narrow dam of clay mixed with a certain proportion of sand. The puddle wall should not be less than from 6 to 8 ft. thick at the top of the dam, and should be given a slight batter on each side. It is constructed during the building of the dam, and should be protected from contact with the water by a considerable thickness of earth on the upper face. The upper face of an earthen dam is frequently protected by means of plank or a pavement of stone. The lower face is frequently protected by means of sod, or sod and willow trees. Sometimes earth dams are provided with a masonry core in place of the puddle wall, to render them water-tight. This consists of a masonry wall carried to an impervious stratum, and up through the center of the dam. The masonry core should never be less than 2 or 3 ft. At the regular water level, earthen dams are liable to have a small bench or shelf formed, and on this account, during the construction, such a bench or shelf is sometimes built into the earth dam. Fig. 18 shows a dam with a masonry core, with the upper face covered with rubble and the lower face evered with grass.

Débris Dems.—These are dams or obstructions placed across the bed of streams to hold back tailings from mines, and to prevent damage to the valleys below. They are made of stone, timber, or brush. No attempt is made to render the débris dam water-tight, the only object being that it should retard the flow of the stream and give it a greater breadth of discharge, so that the water naturally drops and deposits the sediment that it is carrying. The sediment soon silts or fills up against the face of the dam, the area above the dam becoming a flat expanse or plain over which the water finds its way to the dam. When these dams are constructed of stone, the individual stones on the lower face and crest of the dam should be so large that the current will be unable to displace them, while the upper face and core of the dam may be composed of finer material. In case a breach should occur in the débris dam, it will not necessarily endanger the region farther down the stream, as is the case when a break occurs in a water dam. The reason for this is that the débris dam is not made watertight, and hence there is never much pressure against it, or a large volume of water held back that can rush suddenly down the stream should a break

occur. The only result of the break would be that more or less of the gravel behind the dam would be washed through the breach.

Wing Dams.—Wing dams are used for turning streams from their courses, so as to expose all or a portion of the bed for placer mining or other purposes. They are usually of a temporary nature, and are constructed of brush and stones, light cribs filled with stones, and of large stones, or timber. Sometimes the course of a stream is turned by an obstruction made of sand bags, and a wing dam constructed behind this of frames of timber, the intervening space being filled with gravel or earth, and, in some cases, the timber being covered with stone, and the surface riprapped so that if the flow ever comes over the top of the structure it will not destroy it.

Masonry Dams.—When high masonry dams are to be employed they should be designed by a competent hydraulic engineer. Masonry dams are not, as a rule, used for hydraulic mining, owing to the fact that the length of time during which the dam is required rarely warrants the expense of the con-

struction of a masonry dam.

WATER-POWER.

The Theoretical Efficiency of the Water-Power.—The gross power of a fall of water is the product of the weight of water discharged in a unit of time, and the total head or difference in elevation of the surface of the water, above and below the fall. The term head, used in connection with waterwheels,

is the difference in height between the surface of water in the penstock and that in the tailrace, when the wheel is running.

if Q = cubic feet of water discharged per minute, **and** H = total head in feet, **and** WQH = gross power in foot-pounds per minute, **and** WQH = gross power of pounds per minute, **and** WQH = gross power of pounds per minute, **and** WQH = gross power of pounds per minute,

Substituting the value for W, we have

 $\frac{QH\times62.5}{33.000} = .00189 QH, \text{ as the horsepower of a fall.}$

The total power can never be utilized by any form of motor, owing to the fact that there is a loss of head, both at the entrance to, and exit from, the wheel, and there are also losses of energy, due to friction of the water in passing through the wheel. The ratio of the power developed by the wheel to the gross power of the fall, is the efficiency of the wheel. A head of water can be made use of in any one of the following ways:

1. By its weight, as in the water balance, or overshot wheel.

By its pressure, as in the hydraulic engine, hydraulic presses, cranes, etc., or in a turbine water wheel.

By its impulse, as in the undershot and impulse wheels, such as Peltons, etc.

By a combination of the above.

The Horsepower of a Running Stream.—The gross horsepower, as seen above, is

H. P. =
$$\frac{QH \times 62.5}{33,000}$$
 = .00189 QH,

in which Q is the quantity in cubic feet per minute actually impinging on the float or bucket, and H the theoretical head added to the velocity of the stream, or

 $H=rac{v^a}{2g}=rac{v^a}{64.4},$

in which v is the velocity in feet per second.

For example, if the floats of an undershot waterwheel were 2 ft. \times 10 ft., and the stream had a velocity of 3 ft. per second, i. e., v=3, we would have

$$H = \frac{9}{64.4}$$
 = .139, and $Q = 2 \times 10 \times 3 \times 60$ = 3,600 cu. ft. per min.

From this, H. P. = $3.600 \times .139 \times .00189 = .945$ H. P., or a gross horse-power for practically .05 sq. ft. of wheel surface; but, under ordinary circumstances, it would be impossible to attain more than 40% of this, or practically .02 horsepower per sq. ft. of surface, which would require 50 sq. ft. of float

surface to each horsepower furnished.

Current Meters.—A current motor fully utilizes the energy of a stream only when it is so arranged that it can take all of the velocity out of the water; that is, when the water leaves the floats or vanes with no velocity. It is evident that in practice we can never even obtain a close approximation to these results, and hence only a small fraction of the energy of a running stream can be utilized by the current motor. Current motors are frequently used to obtain small amounts of power from a large stream, as, for instance, for pumping a limited amount of water for irrigation. For this work, an ordinary undershot wheel having radial paddles is usually employed. At one end of the wheel a series of small buckets are placed, and so arranged that each bucket will dip up water at the bottom of the wheel and discharge it into the launder, near the top of the wheel. The shape of the buckets should be such that only the amount of water which the bucket is capable of carrying to the launder will be dipped up, for, if the bucket is constantly slopping or pouring water as it ascends, a large amount of useless work is performed in raising this extra water and then pouring it out again, as only the portion that reaches the launder can be of any service. Current motors are not practicable for furnishing large amounts of power.

UTILIZING THE POWER OF A WATERFALL.

The power of a waterfall may be utilized by a number of different styles of motors, but each has certain advantages.

Breast and Undershot Wheels.—When the head is low (not over 5 or 6 ft.), breast or undershot wheels are frequently employed. If these are properly

proportioned, it is possible to realize from 50% to 70% of the theoretical power of the fall, but the wheels are large and cumbersome compared with the duty they perform, and not often installed at present, especially near manufac-

turing centers.

Overshot Wheels.—For falls up to 40 or 50 ft., overshot wheels are very commonly employed, and they have been used for even greater heads than this. The overshot wheel derives its power both from the impulse of the water entering the buckets, and from the weight of the water as it descends on one side of the wheel in the buckets. The latter factor is by far the more important of the two. When properly proportioned, overshot wheels may realize from 70% to 90% of the power of the waterfall, but they are large and cumbersome compared with the power that they give, and are not often installed except in isolated regions, where they are made from timber by local mechanics.

impulse Wheels.—For heads varying from 50 ft. up, impulse wheels are very largely used. These are also sometimes called hurdy gurdies, and are usually of the Pelton type, consisting of a wheel provided with buckets, so arranged about its periphery that they receive an impinging jet of water and turn it back upon itself, discharging it with practically no velocity, and converting practically all the energy into useful work. The efficiency of these wheels varies from 85% to 90% under favorable circumstances. This style of wheel is especially adapted for very high beads and comparatively small wheel is especially adapted for very high heads and comparatively small amounts of water. There are a number of instances where wheels are operating under a head of as much as 2,000 ft. This style of impulse wheel is an American development; in Europe, a style of impulse turbine has been

used to some extent, but has not found very much favor in the United States.

Turbines.—Turbines or reaction wheels are very largely employed, especially for moderate heads. When properly designed to fit the working conditions, they can be used for heads varying from 4 or 5 ft. up to considerably over 100 ft., and when properly placed are capable of utilizing the entire head, a factor that gives them a decided advantage over any other style of waterwheel. Turbines are capable of returning 85% to 90% of the theoretical energy as useful power, and are largely used, especially where a

considerable volume of water at a low head, or a smaller volume at a moderate head, can be obtained.

PUMP MACHINERY.

Pumps are employed for unwatering mines, handling water at placer mines, irrigation, water-supply systems, boiler feeds, etc. For unwatering mines, two general systems of pumping are employed. (1) The pump is placed in the mine and is operated by a motor on the surface, the power being transmitted through a line of moving rods. (2) Both the motor and pump are placed in the mine, the motor being an engine driven by steam, compressed air, hydraulic motor, or an electric motor.

Cornish Pumps.—Any method of operating pumps by rods is commonly called a Cornish system. Formerly, the motor in the Cornish system consisted of a steam engine placed over the shaft head, which operated the pump by a direct line of rods. With this arrangement, there is great danger of accident to the engine from the settling of the ground around the shaft, or from fire in the shaft; also, the position of the motor renders access to the To overcome these objections, the engine is frequently placed at one side of the shaft, and the rods operated by a bob; this has become the common practice, and is generally called the Cornish rig. The engine employed in the most modern plants is generally of the Corliss type, and is provided with a governor to guard against the possibility of the engine running away, in case the rods should break.

This system requires no steam line down the shaft, and is independent of the depth of water in the mine, so that the pump is not stopped by the drowning of a mine, but the moving rods are a great inconvenience in the

shaft, and they absorb a great amount of power by friction.

Simple and Duplex Pumps.—In the simple pump, a steam cylinder is connected directly to a water cylinder, and the steam valves are operated by tappets. Such a pump is more or less dependent on inertia at certain points of the stroke to insure the motion of the valves, hence will not start from

my place, but is liable to become stalled at times. In the duplex pump, by steem cylinders and two water cylinders are arranged side by side, and the valves so placed that when one piston is at mid-stroke it throws the steam valve for the other cylinder, etc. With this arrangement, the pump will start from any point, and can never be stalled for lack of steam, due to the position of the valves. Ordinarily, duplex pumps are to be preferred for mine work.

The packing for the water piston of a pump may be either inside or outside. Any form of packing that is inside the cylinder, either upon a moving piston

or surrounding the ram, and so situated that any wear will allow communication between the opposite ends of the cylinder, is called inside packing It may consist simply of piston rings about the piston, as in the case of an ordinary steam-engine piston G, Fig. 19, or stationary rings may be employed about the outside of a mov-

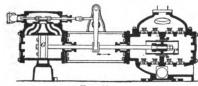


FIG. 19.

ing ram or long piston P.

In either case, the cylinder heads have to be removed before the condition of the packing can be inspected, and any leak does not make itself visible.

When outside packing is employed, separate rams are used in opposite ends of the cylinder, there being no internal communication between the chambers in which the rams work. The rams are packed by ordinary outside stuffingboxes and glands. The arrangement consists practically of two single-acting pumps arranged to work alternately, so that one is forcing water while the other is drawing water. Fig. 20 shows a horizontal section of a callinder as arranged.

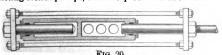
of a cylinder so arranged, together with the yoke rods that operate the ram at the farther end of the cylinder.

As a rule, inside-packed pumps should be avoided in mines, on account of the fact that acid or gritty waters are liable to cut the packing, and make the pumps leak in a very short time. For dipping work in single stopes or entries, small single or duplex outside-packed pumps may be employed. It is generally best to operate such pumps by compressed air, for the exhaust will then be beneficial to the mine air. If steam is employed, it is frequently uecessary to introduce a trap and remove entrailed water from the steam before it enters the pump, and to dispose of the exhaust by piping it out or condensing it. Such isolated steam pumps are about the most wasteful form of steam-driven motor in existence.

For sinking, center-packed single or duplex pumps are usually employed, the duplex style being the better. For station work, where much water is to be handled, large compound, or triple-expansion, condensing, duplex pumping engines are employed. They may, or may not, be provided with cranks and a flywheel. Engineers differ greatly upon this point, and, as a rule, for

very high lifts and great pressures, the flywheel is employed.

The main points in consideration are the first cost of the pump, and the The large amount that will be saved by using the more expensive engine. flywheel pumping engines are several times as expensive as the directacting steam pumps, and the question is as to whether their greater efficiency



will more than counterbalance the increased outlay. Most engineers favor flywheel pumps for handling large volumes of water where the work is approxi-

mately constant, and direct-acting pumps, without flywheels or cranks, for handling small amounts of water, or for very irregular service, owing to the fact that if the flywheel pump is driven below its normal speed it does not govern properly, nor work economically. Until recently, water was removed from mines in lifts of about 300 to 350 ft., pumps being placed at stations along the shaft.

While a series of station pumps are still employed, in some cases they are

generally intended to take care of water coming into the shaft, or working at or near their level, and are not employed for handling water in successive stages or lifts. For handling the bulk of the water from the bottom of the shaft, large pumping engines are employed that frequently force the water to the surface from depths of over 1,000 ft. These high-duty pumping plants, when near the shaft and operated by steam with a condenser, frequently show a very high efficiency. When air is employed to operate such a plant a much higher efficiency can be obtained if the compressed air is heated before using in the high-pressure cylinder and during its passage from the before using in the high-pressure cylinder, and during its passage from the high-pressure to the low-pressure cylinder. This has been very successfully accomplished by means of a steam reheater, the small amount of steam necessary being conveyed to the station in the small pipe, and entirely condensed in the reheater, from which it is trapped as water.

The duty of steam pumps is approximately as follows: For small-sized steam pumps, the steam consumption is from 130 to 200 lb. per horsepower steam pumps, the steam consumption is from 130 to 200 lb. per horsepower per hour, when operating in the workings of a mine at some distance from the boiler. For larger sizes of simple steam pumps, the consumption runs from 30 to 130 lb. of steam per horsepower per hour. Compound-condensing pumps, such as are commonly used as station pumps, consume from 40 to 70 lb. of steam per horsepower per hour. Triple-expansion, condensing high-class pumping engines consume from 24 to 26 lb. per horsepower per hour. The Cornish pump consumes varied amounts of steam in proportion to the water delivered, depending largely on the friction of the gearing. bobs, rods, etc., but its efficiency is usually considerably below the best class of pumping engines.

bobs, rods, etc., but its efficiency is usually considerably below the best class of pumping engines.

Speed of Water Through Valves, Pipes, and Pump Passages.—The speed of water through the valves and passages of a pump should not exceed 250 ft. per minute, and care should be taken to see that the passages are not too abruptly deflected. The flow of water through the discharge pipe should not exceed 500 ft. per minute, but for single-cylindered pumps it is usually figured at between 250 and 400 ft. per minute. In the case of very large pumps, greater velocities may be allowed. The suction pipe for the pump should be larger than the discharge pipe. Ordinarily, the suction pipe for a pump should not exceed 250 ft. in length, and should not contain more than two elbows. The following formula gives the diameter of the suction and discharge pipes of a pump: discharge pipes of a pump: G = U. S. gallons per minute; d' = diameter of suction pipe in inches;

d"= diameter of discharge pipe in inches;

$$d' = \text{diameter of discharge pipe in inches}$$

 $d' = 4.95 \sqrt{\frac{G}{v'}};$

$$d''=4.95\sqrt{\frac{G}{M}}.$$

v' = velocity of water in feet per second in the suction pipe = from .50 v" to .75 v";

v'' = velocity of water in feet per second in the discharge pipe.

RATIO OF STEAM AND WATER CYLINDERS IN A DIRECT-ACTING PUMP.

H = head of water = 2.309 v: A =area of steam cylinder; A= area of steam cylinder; H= head of water =2.309~p; D= diameter of steam cylinder; d= area of pump cylinder; d= diameter of pump cylinder;

square inch;

p =pressure per square inch, corresponding to the head H = .433 H;

 $E = \text{efliciency of pump} = \frac{\text{work done in pump cylinder}}{\text{work done in steam cylinder}}$

$$A = \frac{ap}{EP}; \qquad d = D\sqrt{\frac{EP}{p}}; \qquad \frac{A}{a} = \frac{p}{EP} = \frac{A33H}{EP};$$

$$a = \frac{EAP}{p}; \qquad P = \frac{ap}{EA};$$

$$D = d\sqrt{\frac{p}{EP}}; p = \frac{EAP}{a}; H = 2.309 EP \times \frac{A}{a}.$$

If
$$E = 75\%$$
, then $H = 1.732 P \times \frac{A}{a}$.

E is commonly taken at from .7 to .8 for ordinary direct-acting pumps for the highest class of pumping engines it may amount to .9. The steam ressure P is the mean effective pressure, according to the indicator diagram; the pressure p is the mean total pressure acting on the pump plunger priston, including the suction, as would be shown by the indicator diagram of the water cylinder. The pressure on the pump cylinder is frequently such greater than that due to the height of the lift, on account of the friction in the valves and passages, which increases rapidly with the velocity of the flow. **of** the flow.

Piston Speed of Pumps.—For small pumps, it is customary to assume a speed of 100 ft. per minute, but, in the case of very small short-stroke pumps, this is too high, owing to the fact that the rapid reverses make the flow through the valves and change in the direction of the current too frequent. When the stroke of the pump is somewhat longer (18 in. or more), higher speeds can be employed, and in the case of large pumping engines having long strokes, speeds of as much as 200 to 250 ft. per minute are successfully used without jar or hammer.

Beiler Feed-Pumps.—In practice, it has been shown that a piston speed greater than 100 ft. per minute results in excessive wear and tear on a boiler feed-pump, especially when the water is warm. This is due to the fact that vapor forms in the cylinders, and results in a water hammer. In determining the proper size of a pump for feeding a steam boiler, not only the steam employed in running the engine, but that necessary for the pumps, heating system, etc. must be taken into consideration.

THEORETICAL CAPACITY OF PUMPS AND THE HORSEPOWER REQUIRED TO RAISE WATER.

Let

= cubic feet of water per minute; U. S. gallons per minute; = U. S. gallons per hour; diameter of cylinder in inches; = stroke of piston in inches; number single strokes per minute; speed of piston in feet per minute;
 weight moved in pounds per minute; = pressure in pounds per square feet = $62.5 \times H$; = pressure in pounds per square inch = $.433 \times H$ · = height of lift in feet; H. P. = horsepower. $Q = \frac{\pi}{4} \cdot \frac{d^2}{144} \cdot \frac{lN}{12} = .0004545 N d^2 l.$

Then.

 $\frac{Nd^2l}{300} = .0034 \ Nd^2l. \quad G' = .204 \ Nd^2l.$ The diameter of piston required for a given capacity per minute will be

 $d=46.9\sqrt{\frac{Q}{Nl}}=17.15\sqrt{\frac{G}{Nl'}}$ or $d=13.54\sqrt{\frac{Q}{v}}=4.95\sqrt{\frac{G}{v}}$. The actual capacity of a pump will vary from 60% to 95% of the theoretical capacity, depending on the tightness of the piston, valves, suction pipe, etc.

H. P. =
$$\frac{QP}{33,000} = \frac{QH \times 144 \times .433}{33,000} = \frac{QH}{529.2} = \frac{Gp}{1,714.5}$$

The actual horsepower required will be considerably greater than the theoretical, on account of the friction in the pump; hence, at least 20% should be added to the power for friction and usually about 50% more is added to cover leaks, etc., so that the actual horsepower required by the pump is about 70% more than the theoretical.

EXAMPLE 1.—If it is desired to find the size of a pump that will throw 30 gal. of water per minute up 125 ft., from the bottom of a pit or prospect shaft to the station pump at the main shaft, it may be accomplished as follows:

An allowance of probably 25% should be made with a small pump of this character, to overcome slippage or leaking through the valves, past the piston, etc., and hence we will call the total amount of water to be handled 40 gal. per minute. The formula for the diameter of piston is

$$d=4.95\sqrt{\frac{G}{v}}.$$

Assuming that v = 100 ft. per minute, we have

 $d = 4.95 \sqrt{.4} = 4.95 \times .63 = 3.13$.

In practice, a 31" pump would probably be employed. EXAMPLE 2.—If it is desired to find the approximate horsepower necessary to lift 30 gal. per minute in the above example, without determining the size of the pump, it can be done as follows:

H. P. =
$$\frac{G \times p}{1,714.5} = \frac{30 \times .433 \times 125}{1,714.5} = .95$$
, or practically 1 H. P.

In order to cover leakage through valves, friction, etc., an addition of at least 75% should be made to a very small pump like this, and so we would

count on 11 H. P.

Both of Suction.—Theoretically, a perfect pump will raise water to a height of nearly 34 ft. at the sea level; but, owing to the fact that a perfect vacuum can never be attained with the pump, that the water always contains more or less air, and that more or less watery vapor will form below the piston, it is never possible to reach this theoretical limit, and, in practice. it is not possible to draw water much, if any, over 30 ft. at the sea level, even when the water is cold. Warm water cannot be lifted as high as cold water, owing to the fact that a larger amount of watery vapor forms. With boiler feed-pumps handling hot water, the water should flow to the pumps by gravity.

Amount of Water Raised by a Single-Acting Lift Pump.-In the case of all pumps having a piston or ram, the amount of water lifted is usually considerably less than the piston displacement, owing to the leakage through the valves, etc., but with single-acting lift pumps, having bucket plungers with a clack valve in the plunger, the amount lifted may actually exceed the plunger displacement, that is, the volume of water may actually be greater than the length of the stroke multiplied by the number of strokes, for, during the up stroke, the water both above and below the piston is set in motion, and during the down stroke, the inertia of the water actually carries more water through the valve than would pass through it on account of the space passed through. This increases as the speed or number of strokes increases

Pump Valves.—As a rule, a large number of small valves having a comparatively small opening are preferable to a small number of large valves with a greater opening, and most modern pumps are built upon these lines. A small valve represents a proportionately larger surface of discharge with the same lift than the large valve, hence whatever the total area of the valve-seat opening, its full contents can be discharged with less lift through numerous small valves than through one large valve. Cornish pumps

generally have one large metal valve.

Power Pumps.—Where comparatively small amounts of water are to be handled, and power is available, belt-driven power pumps are very much more efficient than small steam pumps.

Electrically Driven Power Pumps .- Where water is to be delivered from isolated workings to the sumps for the large station pumps, electrically driven power pumps are far more efficient than steam pumps. In some cases it is probably best to equip the entire mine with electric pumps, both in the isolated workings and at the stations, on account of the fact that they can be driven by a high-class compound-condensing engine on the surface. directly connected to a generator, and furnishing electricity through conductors to the various pumps.

The total efficiency of a series of small electric pumps that aggregate a sufficient amount of power to enable this arrangement to be used, is very sumclent amount of power to endote this arrangement to be used, is very much higher than the total efficiency of a number of small isolated steam or compressed-air pumps introduced into the workings. With compound-condensing engines upon the surface, operating electric pumps underground, the steam consumption per pump horsepower per hour, for the smaller sizes, would only be about 40 lb. per horsepower per hour; for medium-sized electric pumps, about 30 lb. of steam per hour, and larger sizes from 20 to 30 lb. per horsepower per hour. It will be seen from these figures that for pumping from isolated portions of the mine the electric pump is much more efficient than the steam pump, and owing to the fact that the current can frequently be obtained from the lines operating the underground haulage system, furnishing light, etc., it is evident that this system of pumping has a great future before it in connection with mining.

The following table gives the gallons per minute delivered from various sized pumps operating at different piston speeds:

PUMP AND WATER MEMORANDA.

1919 Tefer	Area.	Conte	Contents for 1 Ft. Length			ð	allons per	Gallons per Minute Delivered at Indicated Piston Speeds.	Delivered	st Indic	ated Pis	ton Spee	ds.		
Diam Cylin	Sq. In.	Cuble Feet.	Gallons.	8	125	150	176	200	225	250	275	300	850	400	200
1	7854	1		4.1	1	l	1	1		1	11 %	1	1	ı	
, દે _વ	3.1416	0218	1632	16.3	8.4	24.5	88	32.6	36.7	8.0	4	49.0	57.1	65.3	81.6
3,	7.0686	•	•	36.7							101.0				
4	12.5660	•	•	65.3			_	_	•		170.0				
ž	19.6350	•	ب	105.0	_	_	_	•	•	-	281.0				
۶,	28.2740	_ :	ب	147.0	184.0	0.02	257.0	_	•••	367.0	404.0	•			
, , 19	33.1830		ب	172.0	•••	_	302.0	_	88	431.0	474.0	_			
1	38.4850		-	200.0	•••	_	350.0	•	٠	200.0	550.0	_			H
7.	44.1790		ď	0.08 80.08	••	•	_	459.0		574.0	631.0	_			7
òc	50.2650	•	ci	0.198		392.0	_	_	_	653.0	718.0	-		_	H
\. 8	56.7450	٠	Q	295.0	369.0	-	516.0	-	_	737.0	811.0		٦,	_	H
કે.	63.6170			331.0	•			_	•	826.0	0.60	-	ť	_	1,652.0
\ * 6	70.8820	•	က	368.0	•		_				1,013.0	ä	1,289.0	1,473.0	1,842.0
10,	78.5400	-	4	408.0			•		918.0	2	1,122.0	1.224.0	1,428.0	1,632.0	2,040.0
10}	86.5900		•	450.0	262.0		787.0	•	ä	1,125.0	1,237.0	1,349.0	1.574.0	1,799.0	ď
11′′	95.0330	•		494.0	_			٠.	_	1,234.0	1,358.0	1,481.0	1,728.0	1,975.0	ď
114′	103.8700	-		240.0		809.0	•	2	-	1,349.0	1,484.0	1,619.0	1,889.0	2,158.0	2,698.0
12,	113.1000	_		588.0	734.0		끍	Ξ,	ä	1,469.0	1,616.0	1,763.0	2,056.0	2,350.0	2,988.0
_	122.7200	_		88 88 98 98		٠.	1,116.0	11,275.0	ä	1,594.0	1,753.0	ä	2,231.0	2,550.0	3,188.0
_	132.7300	_		0.069	862.	1.68.0	1,307.0	1,379.0	1,551.0	1,724.0	1,896.0	2,069.0	2,413.0	2,758.0	3,448.0
134	143.1400				-	1,115.0	1,301.0	1,487.0	∺	ü	2,045.0	સં	2,603.0	2,974.0	3,716.0
_	153.9400	=			급	1,200.0	1,399.0	1,599.0	1,799.0	1,999.0	2,199.0	2,399.0	2,799.0	3,199.0	3,998.0
_	165.1300	1.1470			Ξ,	1,287.0	1,501.0	1,716.0	1,930.0	2,145.0	2,359.0	ci e	3,002.0	3,431.0	200
a.	1/6./100	0.777	9.1800	918.0	1,148	1,377.0	0.000	1,830.0	0.000.0	0.027	7.550	ci e	3,213.0	3,672.0	4,590.0
, * ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ?	188.6900	1.3100	9.3010	_,	S. S.	1,470.0	1,715.0	1,900.0	0.002.2	4.000	2.650.0	0.00	3,430.0	3,920.0	9000
<u>.</u> 39.	201.0000	1.3900	004	5. 5.	1,500	0.000	0.726,1	2,000	2,349.0	2,610.0	2,871.0	3,132.0	0.604	4,1/6.0	0.00
104	213.8200	0025	300	1,111.6	1,339.	0.799.1	1.94	7.77	2,500.0	2,778.0	3,055.0	3,333.0	3,889.0	14.0	5,556.0
1	220.3900	00/01/	006/-11	1,179.0	7.7	7,709.0	2,003.0	2,000.0	2,039.0	0.03	3,242.0	5,557.0	4,127.0	4,710.0	0.000
10°4'	240.5300	1.6700	12.4900	1,249.0	1,361.	1,873.0	2,180.0	2,456.0	2.810.0	3,122.0	0.45	3,747.0	4,371.0	96.0	6,244.0
	26000	1 9670	19.000	906.1	1,000	000	0.449.0	200	0.076.2	9000	0.000.0	1000	0.720.4	2,000.0	0.010.0
٠.	-	11 0600	14 7300	1,550	5	0.016	9.578	0.26.0	3 314 0	3,683,0	100	4 410 0	156.0	800	2,000
161 88		2.0740	15.5100	1.551.0	1.939	2 327 0	2.714.0	3.102.0	3.490.0	3.878.0	265.0	4.653.0	5,429.0	6.204.0	7.56.0
CA		0.2.1820	16.3200	1,632.0	2,040.0	2,448.0	2,856.0	3.264.0	3,672.0	1,080.0	4,488.0	4,896.0	5,712.0	6,528.0	8,160.0
54%	452.3900	3.1420	23.5000	2,350.0	2,938.0	3.525.0	4,112.0	4.700.0	5.288.0	5,875.0	6.463.0	7,056.0	8,225.0	9,400.0	11,750.0

1 gal. = 231 cu. in. = .13368 cu. ft. 1 gal. of water at 39.2° = 8.33888 lb. 1 cu. ft. of water = 7.48052 gal., and weighs 62.423 lb.

MISCELLANEOUS FORMS OF WATER ELEVATORS.

Jet Pump.—In this form, the energy of the jet of water is utilized for raising a larger volume through a small distance, or a mixture of water and solid material through a short distance.

Vscuum Pump.—The pulsometer, which is the most important representative of this class, consists of two chambers in a large casting, with suitable automatic valves arranged at the top and bottom of the chambers. Steam is introduced into one of the chambers, then the valve at the top closed. This steam will condense, forming a vacuum that draws water from the suction into the chamber. When the chamber is filled with water, steam is again introduced and forces the water out through the discharge pipe. The operation is then repeated, more water being drawn in by the condensation of the steam. The two chambers work alternately, one being engaged in drawing water in while the other forces it out. The total steam efficiency of this form of pump is small, though it may actually be above that of small steam pumps employed in isolated portions of a mine. The advantages are that the pump possesses no intricate mechanism, no reciprocating parts, requires no lubrication, and is not injured by gritty or acid materials. On this account it may be employed for pumping water in concentration works, coal-washing plants, and similar places where the water is liable to contain grit or dirt.

Air-lift Pumps.—By introducing compressed air at the bottom of a pipe submerged in any liquid, the air in the pipe rises as bubbles, and so reduces the specific gravity of the fluid in the pipe. This causes the fluid in the pipe to rise above the level of that surrounding the pipe. The difference in specific gravity can never be great, and hence the fluid can never be elevated to any considerable height without having the lower end immersed to a correspondingly great depth. On this account it is frequently necessary to drill a well considerably below the water-bearing strata, so as to obtain the proper ratio between the submerged portion of the pipe and the height to which the water is to be lifted. Some advantages of this form of pump are that there are no moving parts, no lubrication is required, and gritty material does not interfere with the operation. If the pump is constructed of suitable material, it may be employed for handling acids or solutions in electrolytic or chemical works. This style of pump is also quite extensively employed for pumping water from Artesian wells. It has not been successful as a mine pump, owing to the ratio between the part immersed and the lift.

Centrifugal Pumps.—The height of lift depends on the tangential velocity of the revolving disk of pump and the quantity of water discharged, and is proportional to the area of the discharge orifices at the circumference of the disk. The most efficient total lift for the centrifugal pump is, approximately, 7f. ft., and for small lifts the centrifugal pump is much more efficient than any style of piston pump. For a given lift, the total efficiency of a centrifugal pump increases with the size of the pump. Centrifugal pumps are always designated by the size of their outlet, as, for instance, a 2" or 4" pump, meaning with a 2" or 4" discharge pipe. Centrifugal pumps are not at all effective for dealing with great heads, and hence have never come into competition with piston pumps for this class of work. For lifting large volumes of water against a low head, as in irrigation or drainage problems, they are remarkably efficient. Under the most favorable circumstances, the efficiency of the centrifugal pump may be practically 70%; that is the pump may do an amount of work upon the water that is theoretically equal to 70% of the power furnished to the pump. Pumping engines working against high heads, and operated by the most improved class of engines, may attain an efficiency of practically 8%.

Centrifugal Pump as a Dredge.—When dredging is done by means of centrifugal pumps, a greater amount of power is necessary, and the pump has to be run at a greater speed than when pumping water, owing to the fact that the fluid being handled has a greater density than water. When dealing with fine sand, as much as 50% of the bulk of the material handled may be sand, though, as a rule, the amount of solid material in the water dredged only runs from 30% to 35% of the total.

Water Buckets.—Where only a limited amount of water collects in the mine workings, it is frequently removed by means of a special water bucket or water car during the hours that the hoisting engine would otherwise be idle. Where very large amounts of water are to be removed, it has also

en found economical to remove them by means of special water buckets.

ais is especially true in the case of deep shafts.

One of the best illustrations of this class of work is the Gilberton water caft, which has been equipped at the Gilberton Colliery of the Philaphia and Reading Coal & Iron Co. The collieries draining to this shaft cquire the removal of 6,000,000 gal. of water per 24 hours during the wet son, and this has to be lifted from a depth of 1,100 ft. In order to accom-High the work by means of steam pumps, it required a number of pump actions in different parts of the mine, each of which had to be attended by pumpman, and a large number of steam lines were required in the mine. order to remove the danger of fire caused by these steam lines, and to Is pense with the large amount of labor otherwise necessary, it was decided to coist the water, and a shaft $22 \text{ ft.} \times 26 \text{ ft.} 8 \text{ in.}$ outside of timbers, was sunk. This shaft contains two compartments 7 ft. × 7 ft., in which the water buckets are operated, and two compartments 7 ft. × 11 ft. 8 in. that are utilized for cages to lower men, timber, and other supplies. The water tanks employed in the special water compartments are 5 ft. 6 in. in diameter, and 14 ft. long. They are provided with a special device sliding on regular cage guides, and empty themselves automatically at the surface by means of a trip or sliding valve. Two pairs of direct-acting hoisting engines, with $45'' \times 60''$ cylinders, operating drums 14 ft. 8 in. in diameter by 15 ft. face, are employed. These operate the water buckets in cages by means of 2''crucible steel ropes, at 50 revolutions per minute, which is equivalent to a piston speed of 500 ft. per minute. The drums will hoist two tanks of 2,400 gal. per minute. This gives an output of 7,000,000 gal. per 24 hours. By alightly increasing the speed of the engine this amount can be increased 10%, which is 25% in excess of the calculated maximum demand on the shaft. The cages in the cage compartments are so arranged that they can be disconnected, and water buckets substituted for them. This would be a total output of over 14,000,000 gal. per 24 hours at the normal speed of the engine. One great advantage of this style of pumping plant is that there is absolutely no fear of drowning the pumps.

Some years ago the Hamilton iron mine, in Michigan, was drowned by some years ago the Hamilton from mine, in Michigan, was drowned by a sudden inrush of water that drove the pumpmen from the pumps. In order to remove this large volume of water, special bailing buckets were substituted for the ordinary mine skips. These bailing buckets ran on the inclined skip road, and unwatered the mine in a remarkably short time.

Sinking Pumps.—Sinking pumps may be either single or duplex in their action, and may be inside or outside packed. Outside-packed single-acting pumps are in many ways preferable, owing to the fact that they are less liable to get out of order. One requisite of any sinking pump is that it should be a paged against a spossible, and that these parts should be so placed

have as few exposed parts as possible, and that these parts should be so placed that they will be protected from injury by blasting to as great an extent as Sinking pumps are usually provided with a telescopic section in the possible. suction pipe, and sometimes also in the discharge pipe, so that they can be moved down several feet without having to break the joints of the piping. Pumps for Acid Waters.—Where mine waters are acid in their nature, brass

or brass-lined pumps are usually employed, and in some cases even wooden pumps have been used, as, for instance, in the Swedish copper mines, though this practice is disappearing in favor of the use of brass or copper linings. The pipes for such pumps should be of brass or copper tubing, or should be lined with some substance that will not be affected by the acid of the water. Sometimes wooden linings are em-ployed, placed as shown in Figs. 21 and 22, Fig. 21 being a section of the pipe with the lining complete, and Fig. 22 a cross-section of one of the individual boards used in the lining. These are usually made of pine about | in. thick, and are grooved on each



FIG. 21. Fig. 22.

end as shown. They are sprung in so as to complete a circle on the inside of the pipe, and then long, thin, wooden keys driven into the grooves. When the water is allowed to go into the pipes, the linings swell and make all joints perfectly tight. Elbows and other crooked sections are lined with sheet lead beaten in with a mallet.

FUELS.

The value of any fuel is measured by the number of heat units that its combustion will generate, a unit of heat being the amount required to heat 1b. of water 1° F. The fuels used in generating steam are composed mainly of carbon and hydrogen, ash, and moisture, with sometimes small quantities Combustible is that portion which will burn; the ash or residue varies from 2% to 36% in different fuels.

The following table gives, for the more common combustibles, the air required for complete combustion, the temperature with different proportions of air, the theoretical value, and the highest attainable value under a steam boiler, assuming that the gases pass off at 320°, the temperature of steam at 75 lb. pressure, and the incoming draft to be at 60°; also, that with chimney draft twice and with blast only the theoretical amount of air is required for combustion.

TABLE OF COMBUSTIBLES.

	Temperature of Combustion.						retical Highest Attainabl Value Un der Boile		
Kind of Combustible.	Pounds per Pound of Combustible.	With Theoretical Supply of Air.	With 14 Times Theoretical Supply of Air.	With Twice Theoretical Supply of Air.	With Three Times Theoretical Supply of Air.	Pounds of Water Raised 1° per Pound of Combustible.	Lb. of Water Evaporated From and at 212°, with 1 Lb. Combustible.	With Chimney Draft.	With Blast, Theoretical Supply of Air at 60°, Gas 320°.
Hydrogen Petroleum		5,750 5,050						18.55	19.90
Carbon Coke	12.13	4,580	3,215	2,440	1,650	14,500	15.00	13.30	14.14
Coal, Cumberland,						15,370		14.28	15.06
Coal, Coking bituminous	11.73	5,140	3,520	2,680	1,810	15,837		14.45	15.19
Coal, Cannel	11.80	4,850	3,330	2,040	1,720	15,080 11,745	15.60	14.01 10.78	14.76 11.46
Peat, Kiln dried	7.68	4,470	3,140	$\frac{2,490}{2.420}$	1.660	9,660	10.00	8.92	9.42
Peat, Air dried, 25% water	5.76	4,000	2,820	2,240	1,550	7,000	7.25	6.41	6.78
Wood, Kiln dried	6.00	4,080	2,910	2,260	1,530	7,245	7.50	6.64	7.02
Wood, Air dried, 20% water	4.80	3,700	2,607	2,100	1,490	5,600	5.80	4.08	4.39

The effective value of all kinds of wood per pound, when dry, is substantially the same. This is usually estimated at .4, the value of the same weight of coal. The following are the weights and comparative values of different woods by the cord:

Wood.	Weight.	Wood.	Weight.
Hickory (shell bark) Hickory (red heart) White oak Red oak Spruce New Jersey pine	4,469 3,705 3,821 3,254 2,325 2,137	Beech	3,126 2,878 3,375 2,680 1,904 1,868

167 SLACK.

Much is said nowadays about the wonderful saving that is to be expected som the use of petroleum for fuel. This is all a myth, and a moment's ttention to facts is sufficient to convince any one that no such possibility mists. Petroleum has a heating capacity, when fully burned, equal to from 1,000 to 22,000 B. T. U. per lb., or, say, 50% more than coal. But, owing the ability to burn it with less losses, it has been found, through extended periments by the pipe lines, that under the same boilers, and doing the ime work, 1 lb. of petroleum is equal to 1.8 lb. of coal. The experiments on comotives in Russia have shown practically the same value, or 1.77. Now. gallon of petroleum weighs 6.7 lb. (though the standard buying and selling a gallon of petroleum weighs 6,7 lb. (though the standard buying and selling weight is 6,5 lb.), and therefore an actual gallon of petroleum is equivalent under a boiler to 12 lb. of coal, and 190 standard gallons are equal to a gross but of coal. It is very easy with these data to determine the relative cost. At the wells, if the oil is worth, say, 2 cents a gallon, the cost is equivalent so 33.80 per ton for coal at the same place, while at, say, 3 cents per gallon, the lowest price at which it can be delivered in the vicinity of New York, it costs the same as coal at \$5.70 per ton. The Standard Oil Company estimates that 172 coal are equal to a gross ton of coal allowing for incident lawings. that 173 gal. are equal to a gross ton of coal, allowing for incidental savings,

as in grate bars, carting ashes, attendance, etc.
Sawdust can be utilized for fuel to good advantage by a special furnace and automatic feeding devices. Spent tan bark is also used, mixed with some coal, or it may be burned without the coal in a proper furnace. Its value is about one-fourth that of the same weight of wood as it comes from the press, but, when dried, its value is about 85% of the same weight of wood

in same state of dryness

It has been estimated that, on an average, 1 lb. of coal is equal, for steammaking purposes, to 2 lb. dry peat, 2½ to 2½ lb. dry wood, 2½ to 3 lb. dried tan bark, 2½ to 3 lb. cotton stalks, 3½ to 3½ lb. wheat or barley straw, and 6 to 8 lb. wet tan bark.

Natural gas varies in quality, but it is usually worth 2 to 21 times the same

weight of coal, or about 30,000 cu. ft. are equal to a ton of coal.

Slack, or the screenings from coal, when properly mixed—anthracite and bituminous—and burned by means of a blower on a grate adapted to it, is nearly equal in combustible value to coal, but its percentage of refuse is

greater.

The accompanying table of proximate analyses and heating values of American coals was compiled by Mr. William Kent, for the 1898 edition of the Babcock & Wilcox Co.'s book, "Steam." The analyses are selected from various sources, and, in general, are averages of many samples. heating values per pound of combustible are either obtained from direct calorimetric determinations or calculated from ultimate analyses, except those marked (?), which are estimated from the heating values of coals of similar composition. The figures in the last column are obtained by dividing the figures in the preceding column by 965.7, the number of heat units required to evaporate 1 lb. of water at 212° into steam of the same temperature.

The heating values per pound of combustible given in the table, except those marked (?), are probably within 3% of the average actual heating values of the combustible portion of the coals of the several districts. When the percentage of moisture and ash in any given lot of coal is known, the heating value per pound of coal may be found, approximately, by multiplying the heating value per pound of combustible of the average coal of the district by the difference between 100% and the sum of the percentages of

moisture and ash.

The heating effect is calculated on the basis of the coal burned to carbon dioxide and liquid water at 100° C., and is stated either in calories per kilogram or English heat units per pound. The theoretical evaporative effect is calculated by dividing the number of calories per kilogram by 536, or the number of English heat units per pound by 965. In either case, it expresses number of Enginem near units per pound by 500. In cause case, it captesos the theoretical number of kilograms or pounds of water converted into steam from and at 100° C., by 1 kilogram or 1 lb. of coal.

A committee of the Western Society of Engineers, of Pittsburg, report

that 1 lb. of good coal = $7\frac{1}{4}$ cu. ft. of natural gas. When burned with just enough air, its temperature of combustion is $4,200^{\circ}$ F. The Westinghouse Air Brake Co. found from experiment that 1 lb. Youghlogheny coal = 121 cu. ft. natural gas, or 1,000 cu. ft. natural gas = 81.6 lb. coal. natural gas gives 1,000,000 B. T. U. for 1,000 cu. ft. and weighs .045 lb. per

PROXIMATE ANALYSES AND HEATING VALUES OF AMERICAN COALS.

Coal.	Moisture.	Volatile Matter.	Fixed Carbon.	Ash.	Sulphur.	Heating Value per Lb. Coal, B. T. U.	Volatile Matter Per Cent. of Combustible.	Fixed Carbon.	Heating Value per Lb. Combustible.	Theoretical Evaporation From and at 212° per Lb. Combustible.
		-	-		-		-	-		1
Anthracite. Northern Coal Field . East Middle Coal Field . West Middle Coal Field . Southern Coal Field .	3,42 3,71 3,16 3,09	4.38 3.08 3.72 4.28	83.27 86.40 81.59 83,81	8.20 6.22 10.65 8.18	.73 .58 .50 .64	13,160 13,420 12,840 13,220	5.00 3.44 4.36 4.85	95.00 96.56 95.64 95,15	14,900 14,900 14,900 14,900	15.42 15.42 15.42 15.42
Semianthracite. Loyalsock Field Bernice Basin	1.30 .65	8.10 9.40	83.34 83.69	6.23 5.34	1.63 .91	13,920 13,700	8.86 10.98	91.14 89.02	15,500 15,500	16.05 16.05
Semibituminous. Broad Top, Pa	.79	15.61	77.30	5.40	.90	14.820	17.60		15,800	1 30
Clearfield Co., Pa	.76	22,52	71.82	3,99	.90	14,820	24.60	82.40 75.40	15,800	16.36 16.25
Cambria Co., Pa	.94	19.20	71.12	7.04	1.70	14,450	22.71	77.29	15,700	16.25
Somerset Co., Pa	1.58	16.42	71.51	8.62	1.87	14,200		79.63	15,800	16.36
Cumberland, Md	1.09	17.30	73.12	7.75	.74	14,400	19.79	80.21	15,800	16.36
Pocahontas, Va	1.00	21.00	74.39	3.03	.58	15,070	22.50	77.50	15,700	16.25
New River, W. Va Bituminous.	.85	17.88	77.64	3.36	.27	15,220	18.95	81.05	15,800	16.36
Connellsville, Pa	1.26	30.12	59.61	8.23	.78	14,050	34.03	65.97	15,300	15.84
Youghiogheny, Pa	1.03	36.50	59.05	2.61	.81	14,450	38.73	61.27	15,000	15,53
Pittsburg, Pa	1.37	35.90	52.21	8.02	1.80	13,410	41.61	58.39	14,800	15,32
Jefferson Co., Pa	1.21	32.53	60.99	4.27	1.00	14,370		64.53	15,200	15.74
Middle Kittaning Seam, Pa. Upper Freeport Seam, Pa.	1.81	35.33	53.70	7.18	1.98	13,200	40.27	59.73	14,500	15.01
and Ohio	1.93	35.90	50.19	9.10	2.89	13,170	43.59	56.41	14,800	15,32
Thacker, W. Va	1.38	35.04	56.03	6.27	1.28	14,040	39.33	60.67	15,200	15.74
Jackson Co., Ohio	3.83	32.07	57.60	6.50		13,090	35.76	64.24	14,600	15.11
Brier Hill, Ohio	4.80	34.60	56.30	4.30		13,010	38.20	61.80	14,300	14.80
Hocking Valley, Ohio	6.59	34.97	48.85	8.00	1.59	12,130		57.19	14,200	14.70
Vanderpool, Ky Muhlenberg Co., Ky	4.00	34.10	54.60 55,50	7.30 4.95	1.57	12,770 13,060	38.50 38.86	61.50	14,400 14,400(?)	14.91
Scott Co., Tenn	1.26	35.76	53.14	8.02	1.80	13,700	34.17	65.83	15,100(?)	15,63
Jefferson Co., Ala	1.55	34.44	59.77	2.62	1.42	13,770	37.63	62,37	14,400(?)	14.91
Big Muddy, Ill	7.50	30.70	53.80	8.00	1.12	12,420	36.30	63.70	14,700	15,22
Mt. Olive, Ill	11.00	35.65	37.10	13.00		10,490	47.00	53,00	13,800	14,29
Streator, Ill	12,00	33,30	40.70	14.00		10,580	45.00	55.00	14,300	14.80
Missouri	6.44	37.57	47.94	8.05		12,230	43.94	56.06	14,300(?)	14.80
Iowa	8.45	37.09	35.60	18.86		8,720	51.03	48.97	12,000(?)	12,42
Wyoming	8.19	38.72	41.83	11.26	200	10,390	48.07	51.93	12,900(?)	13.35
Utah	9.29	41.97	44.37	3.20		11,030	48.60	51.40	12,600(?)	13.04
Oregon lignite	15.25	42.98	33,32	7.11	1.66	8,540	54.95	45,05	11,000(?)	11.39

A British thermal unit (B. T. U.) is the quantity of heat required to raise the temperature of 1 lb. of water 1° F. at or near the temperature of maximum density, 39.1° F.

A calorie is the quantity of heat required to raise the temperature of 1 kilogram of water 1° C. at or about 4° C.

A pound calorie is the quantity of heat necessary to raise the temperature of 1 lb. of water 1° C.

1 French calorie = 3.968 British thermal units.

1 B. T. U. = .252 calorie. 1 lb. calorie = § B. T. U. = .4536 calorie.

The heating value of any coal may be calculated from its ultimate analysis, with a probable error not exceeding 2%, by Dulong's formula:

Heating value per lb. = $146 C + 620 \left(H - \frac{O}{9}\right)$

in which C, H, and O are, respectively, the percentages of carbon, hydrogen, and oxygen.

Heat in pound calorie = 8,080
$$C + 34,462 \left(H - \frac{O}{8}\right)$$
,
or = 8,080 $C + 34,462 \left(H - \frac{O}{8}\right) + 2,250 S$.
Heat in B. T. U. = 14,650 $C - 62,100 \left(H - \frac{O}{8}\right)$,

which C, O, H, and S represent the weights of carbon, oxygen, hydroand sulphur in 1 lb. of the substance.

COMPOSITION OF FUELS. (Mechanical Draft, B. F. Sturtevant Co.)

Description.	Carbon.	Hydro-	Oxy-	Nitro-	Sul-	Ash.	
		gen.	gen.	gen.	phur.	21011	
Anthracite.							
rance	90.9	1.47	1.53	1.00	.80	4.3	
ales	91.7	3.78	1.30	1.00	.72	1.5	
hode Island	85.0	3.71	2.39	1.00	.90	7.0	
ennsylvania	78.6	2.50	1.70	.80	.40	14.8	
Semibituminous.							
laryland	80.0	5.00	2.70	1.10	1.20	8.3	
ales	88.3	4.70	.60	1.40	1.80	3.2	
Bituminous.						· · · ·	
ennsylvania	75.5	4.93	12.35	1.12	1.10	5.0	
ndiana	69.7	5.10	19.17	1.23	1.30	3.5	
llinois	61.4	4.87	35.42	1.41	1.20	5.7	
irginia	57.0	4.96	26.44	1.70	1.50	8.4	
labama	53.2	4.81	32.37	1.62	1.30	6.7	
Centucky	49.1	4.95	41.13	1.70	1.40	7.2	
ape Breton	67.2	4.26	20.16	1.07	1.21	6.1	
Vancouver Island	66.9	5.32	8.76	1.02	2.20	15.8	
ancashire gas coal	80.1	5.50	8.10	2.10	1.50	2.7	
Boghead cannel	63.1	8.90	7.00	.20	1.00	19.8	
Lignite.		1					
California brown	49.7	3.78	30.19	1.00	1.53	13.8	
Australian brown	73.2	4.71	12.35	1.11	.63	8.0	
Petroleum.	1					0.0	
Pennsylvania (crude)	84.9	13.70	1.40				
Caucasian (light)	86.3	13.60	.10	1			
Caucasian (heavy)	86.6	12.30	1.10	l í			
Refuse	87.1	11.70	1.20		- 1		

CLASSIFICATION, COMPOSITION, AND PROPERTIES OF COALS.

Coals may be broadly divided into two classes: Anthracite, or hard, coal:

and bituminous, or soft, coal.

Anthracite, or Hard, Coal.—Specific gravity, 1.30 to 1.70. This is the densest, hardest, and most lustrous of all varieties. It burns with little flame and no smoke, but gives a great heat. Contains very little volatile combustible matter. Color, deep black, shining; sometimes iridescent. Fracture, conchoidal.

Semienthracite coal is not so dense nor so hard as the true anthracite. Its percentage of volatile combustible matter is somewhat greater, and it

ignites more readily.

Biteminous, or Soft, Coal.—Specific gravity, 1.25 to 1.40. It is generally brittle; has a bright pitchy or greasy luster, and is rather fragile as compared with anthracite. It burns with a yellow smoky flame, and gives, on distillation, hydrocarbon oils or tar.

lation, hydrocaroon one or tar.

Under the term "bituminous" are included a number of varieties of coal
that differ materially under the action of heat, giving rise to the general
classification: Coking or caking coals, and free-burning coals.

Sembituminous coal has the same general characteristics as the bituminous,
although it is usually not so hard, and its fracture is more cuboidal. The

percentage of volatile combustible matter is less. It kindles readily, and burns quickly with a steady fire, and is much valued as a steam coal.

Coking coals are those that become pasty or semiviscid in the fire; and when heated in a close vessel, become partially fused and agglomerate into a mass of coherent coke. This property of coking may, however, become greatly impaired, if, indeed, not entirely destroyed, by weathering.

Free-burning coals have the same general characteristics as the coking coals, but they burn freely without softening, and do not fuse or cake

together in any sensible degree.

Splint coal has a dull black color, and is much harder and less frangible than the coking coal. It is readily fissile, like slate, but breaks with difficulty on cross-fracture. It ignites less readily, but makes a hot fire, constituting a good house coal.

WEIGHTS AND MEASUREMENTS OF COAL. (Core Proc & Co Chicago III)

Coal.	Weight per Cubic Foot. Pounds.	Cubic Feet per Ton, 2,000 Lb.	Coal.	Weight per Cubic Foot. Pounds.	Cubic Feet
Lehigh lump Lehigh cupola Lehigh broken Lehigh egg Lehigh stove Lehigh nut Lehigh pea Lehigh pea Lehigh buckwheat Lehigh dust	55.26 55.52 56.85 57.74 58.15 58.26 53.18 54.04 57.25	36.19 36.02 35.18 34.63 34.39 34.32 37.60 37.01 34.93	Free-burning egg Free-burning stove Free-burning nut Pittsburg Illinois Connellsville coke Hocking Indiana block Erie Ohio cannel	56.07 56.33 56.88 46.48 47.22 26.30 49.30 43.85 48.07 49.18	35.36 35.36 42.36 42.36 42.36 43.56 45.61 41.61 40.66

Cannel coal differs from the ordinary bituminous coal in its texture. It is compact, with little or no luster and without any appearance of a banded structure. It breaks with a smooth conchoidal fracture, kindles readily, and

burns with a dense smoky flame. It is rich in volatile matter, and makes an excellent gas coal. Color, dull black and grayish black.

Lignite, or brown coal, often has a lamellar or woody structure; is sometimes pitch black, but more often rather dull and brownish black. It kindles readily and burns rather freely with a yellow flame and comparatively little smoke, but it gives only a moderate heat. It is generally non-coking. The

percentage of moisture present is invariably high—from 10% to 30%.

The subdivisions given above are entirely arbitrary, as the different varieties of coal are found to shade insensibly into one another. The following are two classifications according to percentages of volatile combustible

matter:

CLASSIFICATION OF COAL ACCORDING TO VOLATILE COMBUSTIBLE.

mianthracite mibituminous tuminous	Per Cent.	Kent. Per Cent.
Anthracite Semianthracite Semibituminous Bituminous Lignite	2.5 to 6 7 to 10 12 to 20 over 20	0 to 7 7.5 to 12 12.5 to 25 25 to 50 over 50

The Composition of Coals.—A proximate analysis determines the proportion of those products of a coal having the most important bearing on its uses. These substances as usually presented are: Moisture, or water, volatile comstible matter, fixed carbon, sulphur, and ash. In addition to these, the allowing physical properties are generally given: Color of ash, specific avity, and strength or hardness. The determination of these eight factors was a fair general idea of the adaptabilities of a coal.

• Meisture, or water, in coal, has no fuel value, is an inert constituent, dug, mand hauled, and finally expelled at a cost of fuel. Each per cent. f moisture means 20 lb. less fuel for each ton of coal.

Volatile combustible matter is an important constituent of coal, the amount and quality deciding whether a coal is suitable for the manufacture of illuminating gas. The coking of coal also is largely dependent on this constituent. When a large percentage of volatile combustible matter is present, coals ignite easily and burn with a long yellow fiame, and, in ordinary combustion, give out dense smoke, and form soot. This quality makes a fuel objectionable for railway and sometimes for naval use.

The fixed carbon is the principal combustible constituent in coal, and, in bituminous and semibituminous coals, the steaming value is in proportion to the percentage of fixed carbon. Though the fixed carbon of a coal evaporates much less water than an equivalent weight of the volatile combustible matter when properly burnt, in practice, so much of the latter is lost through careless firing, or improper furnace construction, that the relative steaming value of a coal may be fairly approximated by assuming the carbon to be

the only useful constituent.

Sulphur will burn and develop heat, and is not inert like moisture and as. But it corrodes grates and boilers; in the blast furnace it injures iron, and produces a hot short pig, and is objectionable in coal for forge use. In gas making, the sulphur must be removed. It usually occurs in coal in the form of iron pyrites, which, oxidizing, causes disintegration, and sometimes spontaneous combustion. It is then an element of danger and loss.

Ash is an inert constituent, which means 20 lb. of weight to be handled and 20 lb. loss per ton of coal for each per cent. present. Water in coal is removed at the cost of fuel, while ashes are removed at extra cost of labor. It is estimated that if the cost of stoking coal is 64% of the cost of coal (coal at \$3.00 per ton, and labor at \$1.00 per day), and with cost of handling ashes double that of stoking coal, 5% of ash will lessen the fuel value of coal over

6%; 10% ash, over 12%; and so on.

The color of the ssh furnishes a rough estimate of the amount of iron contained in a fuel. Iron in an ash makes it more fusible, and increases its tendency to clinker. In domestic consumption, where the temperature is low, the quantity of ash is of more importance than its fusibility, but for steam purposes, where an excessive heat is required, ashes of a clinkering coal will fuse into a vitreous mass and accumulate upon the grate bars and exclude the passage of necessary air. The practicability of employing a coal will often be determined by the quality of the clinkering of the ashes. Under such conditions, such coals are best whose ashes are nearly pure white and which contain little or no alkali nor any lime, and do not contain silica and alumina.

The specific gravity is an important factor when there is restriction of space, as on railway cars and in ship bunkers. A given bulk of anthracite coal will weigh from 10% to 15% more than the same bulk of bituminous coal, so that from 10% to 15% more pounds of fuel can be carried in the same place. The average specific gravity of anthracite coal is 1.5, and a cubic yard weighs

about 2,531 lb.

The average specific gravity of American bituminous coals, and of grades intermediate between them and anthracite, is about 1.325, and 1 cu. yd.

weighs about 2,236 lb.

Strength or hardness is valuable in preventing waste. In soft coal, much is ground to dust in mining and at the tipple. In railway transportation, soft coal is crushed, which further increases the loss, and the coal reaches market in bad condition. A very soft coal is shipped in lump, and is not in so wide demand. For marine use, a soft coal is objectionable, because of disintegration by the motion of the ship. Strength is a requisite for the use of raw coal in the blast furnace, and also to prevent excessive loss of coal through the grates in ordinary furnaces.

Steaming Cosis.—For steam making, the superiority of coals high in combustible constituents is admitted, and those with the higher percentage of fixed carbon are the most desirable. But the consideration of the steaming qualities of a coal involves, also, a consideration of the form of furnace and of all the conditions of combustion. The evaporative power of a coal in

172 FUELS.

practice cannot be stated without reference to the conditions of combustion. and every practical test of a coal, to be thorough, should lead to a determination of the best form of furnace for that coal, and should furnish knowledge as to what class of furnaces in actual use such coal is specially adapted. It is not sufficient that in comparative tests of coals the same conditions should exist with each, but there should also be determined the best conditions for each coal.

Of coals high in fixed carbon, the semianthracites and the semibituminous rank as high as the anthracites in meeting the various requirements of

a quick and efficient steaming coal.

For railway use, these coals have been found to excel anthracites in evaporating power. The comparative absence, in semibituminous coals, of smoke, which means loss of combustible matter as well as discomfort to the traveler, is sufficient to suggest the superiority of these coals over bituminous coals for such use. In fact, the high rate of combustion and the strong draft necessary in locomotives is particularly unfavorable to the economic com-bustion of bituminous coal. Such semibituminous coals are also specially well suited for small tubular boilers, firebox steam boilers, or other forms with small unlined combustion chambers, in which the gases from bituminous coals become cooled, are not burnt, and deposit soot in the tubes.

Steaming coal should kindle readily and burn quickly but steadily, and

should contain only enough volatile matter to insure rapid combustion. should be low in ash and sulphur, should not clinker, and when it is to be

transported should not easily crumble and break.

Coals for Iron Making.—For the manufacture of iron and for metallurgical purposes, coal is chiefly used after being converted into coke, though it is also used to a limited extent in the raw state. Coal directly used must be strong and not swell nor disintegrate so as to choke the furnace. It should be capable of producing a high heat and should not contain a large amount of sulphur or phosphorus.

Coke.—Coke is the fixed carbon of a coal, a fused and porous product produced by the distillation of the gaseous constituent. For metallurgical use, it should be firm, tough, and bright, with a sonorous ring, and should contain not over 1% of sulphur. For blast-furnace use, a dense coke is objectionable, and the best is the one with the largest cell structure and the hardest cell wall. A high percentage of volatile hydrocarbon is, as a rule.

necessary for a good coking coal.

The fusibility of the carbon, the amount of disposable hydrogen, the tenacity with which the gaseous constituents are held, all affect the results in coking. Further, coal that is mined near the outcrop, and has been subjected to the influence of the weather, loses its capacity for coking. The process of manufacture should, however, be adapted to the character of the coal, as it has an important, though secondary, influence on the physical character, uniformity of quality, and dryness of a coke. Coals of inferior grade are made to produce good coke by using coke ovens in which the heat of the gases is applied externally to the coke chamber, but the coal is generally first carefully crushed and washed. Further, the depth of the charge and length of heating have an important bearing.

As at present understood, and in the present mode of manufacture, the essential qualities of a good coking coal are: that it shall contain not less than 20% nor more than 30% of volatile hydrocarbons, and not too much ash; that on being heated it must pass through a thoroughly fused or pasty condition; and that when in this condition, it must part with its volatile matter in such

a manner as to form innumerable small pores.

If a coal contains less than 20% of volatile matter, it will not fuse properly while if it has more than 30% the porous structure will be unduly developed at the expense of the strength of the pore walls; on the other hand, many coals lying between these limits will not fuse at all, and therefore do not coke, while others fuse properly but give off their gas so as to form large

and thin-walled pores.

Ordinary analyses do not indicate whether or not a coal is a good coking coal, and they indicate simply by giving the amount of carbon, ash, and sulphur, what will be the probable purity of the coke formed. The coal of the Pittsburg bed in the Connellsville basin of Pennsylvania is considered by many as the standard coking coal, but coals whose analysis differ very materially from that of Connellsville undoubtedly give most excellent cokes, which are equal to or very nearly equal to, that from Connellsville, as, for interest the Beacher or very nearly equal to, that from Connellsville, as, for instance, the Pocahontas coke, Virginia.

Domestic Cosls.—In domestic use, coal is burned in open grates, in closed to ves with ordinary fire bowls and flat grates, or with basket grates in small trnaces for hot-air heating, and in cooking stoves. In all these, the coal sustains a mild, steady combustion, and remains ignited at a low temperature of the coal burner with the coal burner erature with a comparatively feeble draft, is the best. A coal burning with smoky flame is objectionable as producing much soot and dirt, especially br open grates or cooking purposes. For self-feeding stoves, or for base burners, a dry non-coking coal is necessary. A very free and fiercely burning coal is not desirable, particularly in stoves, as the temperature cannot be easily regulated. A sulphurous coal is also bad, as it produces stilling gases with a defective draft, and corrodes the grates and fire bowls. The difficulty

with a defective draft, and corroces the grates and nie bowls. The dimentify from clinkering is not so great in domestic uses, as the temperature is not generally high enough to fuse the ash. A stony, hard ash that will not pass between the grate bars is bad, and light pulverulent ash is best.

Gas Coals.—Mr. H. C. Adams, of The American Gas Light Association, says: "The essentials of a good gas coal are a low percentage of ash, say 5%, and of sulphur, say ½ of 1%, a generous share, say 37% to 40% of volatile matter, charged with rich illuminating hydrocarbons. And it should yield, under present retort practice, 85 candle-feet to the pound carbonized. It should be sufficiently dense to hear transportation well, so that when cerried long sufficiently dense to bear transportation well, so that, when carried long distances, it may not arrive at its destination largely reduced to slack or fine coal of the consistency of sand. And it should possess coking qualities that will bring from the retorts, after carbonization, about 60% of clean, strong,

bright coke.'

Blacksmith Coals.—A good coal for blacksmith purposes should have a high heating power, should contain a very small amount of sulphur. if any, should coke sufficiently to form an arch on the forge, and should also be low in ash.

From the above, it is readily seen that the analysis of a coal does not necessarily determine its value or the uses to which it can be put. ever, by examining the analyses given in the table on page 168, certain even, by calculating the analysis given in the table on page 108, Certain standards may be adopted as showing in a general way about what the analysis of coal should be for certain purposes. For steam purposes, the semibituminous coals have established reputations. For gas coals, that from Youghiogheny, Pa., is well known. For blackmiths, Broad Top and Tioga County, Pennsylvania, coals are standards; while for coking, Connells ville is recognized as a standard.

The sizes of anthracite coal vary. The sizes of screen mesh and bar open-

ings used for separating, range as follows: Lump, over bars placed 7 to 9 in. apart.

Steamboat, over bars placed 3½ to 5 in. apart and through bars 7 in. apart. Grate, over 2½ in. and through 4½ in. square mesh.

Egg. over 2 in. and through 24 in. square mesh.

Stove, over 11 in. and through 2 in. square mesh. Chestnut, over # in. and through 1# in. square mesh.

Pea, over in. and through in. square mesh.

Buckwheat, over 1 in. and through 1 in. square mesh.

No. 2 Buckwheat, or Bird's-eye, over 1 in. and through f_R in. square mesh.

The sizes of bituminous coal are Lump, Nut, and Slack.

All coal that passes over bars 11 in. apart is called Lump. All coal that passes through bars 11 in. apart and over bars 1 in. apart is called Nut.

All coal that passes through bars # in. apart is called Slack.

ANALYSIS OF COAL.

The following is the outline of the method recommended for the analysis of coal by a committee of the American Chemical Society, Messrs. W. F. Hillebrand, C. B. Dudley, and W. A. Noyes:

Sampling.—At least 5 lb. of coal should be taken for the original sample, with care to secure pieces that represent the average. These should be broken up and quartered down to obtain the smaller sample, which is to be reduced to a fine powder for analysis. The quartering and grinding should be carried out as rapidly as possible, and immediately after the original sample is taken, to prevent gain or loss of moisture. The powdered coal should be kept in a tightly stoppered tube, or bottle, until analyzed. Unless the coal contains less than 2% of moisture, the shipment of large samples in wooden boxes should be avoided. of large samples in wooden boxes should be avoided.

174 FUELS.

In boiler tests, shovelfuls of coal should be taken at regular intervals and put in a tight covered barrel, or some air-tight covered receptacle, and the latter should be placed where it is protected from the heat of the furnace.

In sampling from a mine, the map of the mine should be carefully examined and points for sampling located in such a manner as to fairly represent the body of the coal. These points should be placed close to the working face. Before sampling, make a fresh cut of the face from top to bottom to a depth that will insure the absence of possible changes or of sulphur and smoke from the blasting powders. Clean the floor and spread a piece of canvas to catch the cuttings. Then, with a chisel, make a cutting from floor to roof, say 3 in. wide and about 1 in. deep. Do not chisel out the shale or other impurities that it is the practice at that mine to reject. Measure the length of the cutting made, but do not include the impurities in this measurement. With a piece of flat iron and a hammer, break all pieces to quarter-inch cubes or less, without removing from the cloth. Quarter down and transfer to a sealed bottle or jar. For the "run-of-mine" sample, samples taken at several points in this manner should be mixed and quartered down. If the vein varies in thickness at different points, the samples taken at each point should correspond in amount to the thickness of the vein. For instance, a small measure may be filled as many times with the coal of the sample as the vein is feet in thickness. Should there appear differences in the nature of the coal, it will be more satisfactory to take, in addition to the general sample, samples of such portions of the vein sa may display these differences.

Moisture.—Dry 1g. of the coal in an open porcelain or platinum crucible at 104° to 107° C. for 1 hour, best in a double-walled bath containing pure

toluene. Cool in a desiccator and weigh covered.

Volatile Combustible Matter.—Place 1 g. of fresh, undried coal in a platinum crucible, weighing 20 to 30 g., and having a tightly fitting cover. Heat over the full flame of a Bunsen burner for 7 minutes. The crucible should be supported on a platinum triangle with the bottom 6 to 8 cm. above the top of the burner. The flame used should be fully 20 cm. high when burning free, and the determination made in a place free from drafts. The upper surface of the cover should burn clear, but the under surface should remain covered with carbon. To find "volatile combustible matter," subtract the percentage of moisture from the loss found here.

Ash.—Burn the portion of coal used for the determination of moisture at first over a very low flame, with the crucible open and inclined, until free from carbon. If properly treated, this sample can be burned much more quickly than the dense carbon left from the determination of volatile matter.

Fixed Carbon.—This is found by subtracting the percentage of ash from

the percentage of coke.

Sulphur (Eschka's Method).—Mix thoroughly 1 g. of the finely powdered coal with 1 g. of magnesium oxide and ½ g. of dry sodium carbonate, in a thin 75 to 100 c.c. platinum dish or crucible. The magnesium oxide should be light and porous, not a compact, heavy variety. The dish is heated on a triangle over an alcohol lamp, held in the hand at first. Gas must not be used, because of the sulphur it contains. The mixture is frequently stirred with a platinum wire and the heat raised very slowly, especially with soft coals. The flame is kept in motion and barely touching the dish, at first, until strong glowing has ceased, and is then increased gradually until, in 5 minutes, the bottom of the dish is at a low red heat. When the carbon is burned, transfer the mass to a beaker and rinse the dish, using about 50 c.c. of water. Add 15 c.c. of saturated bromine water and boil for 5 minutes. Allow to settle, decant through a filter, boil a second and third time with 30 c.c. of water, and wash until the filtrate gives only a slight opalescence with silver nitrate and nitric acid. The volume of the filtrate should be about 200 c.c. Add 15 c.c. of concentrated hydrochloric acid or a corresponding amount of dilute acid (8 c.c. of an acid of 8%). Boil until the bromine is expelled, and add to the hot solution, drop by drop, especially at first, and with constant stirring, 10 c.c. of a 10% solution of barium chloride. Digest on the water bath, or over a low flame, with wash, using either a Gooch crucible or a paper filter. The latter may be ignited moist in a platinum crucible, using a low flame until the carbon is burned.

In the case of coals containing much pyrites or calcium sulphate, the

residue of magnesium oxide should be dissolved in hydrochloric acid and

the solution tested for sulphuric acid.

When the sulphur in the coal is in the form of pyrites, that compound is converted almost entirely into ferric oxide in the determination of ash, and, since 3 atoms of oxygen replace 4 atoms of sulphur, the weight of the ash is less than the weight of the mineral matter in the coal by it he weight of the sulphur. While the error from this source is sometimes considerable, a correction for "proximate" analyses is not recommended. When analyses are to be used as a basis for calculating the heating effect of the coal, a correction should be made.

The analysis of a coal may be reported in three different forms, as percentages of the moist coal, of the dry coal, or of the combustible. Thus, suppose 1 g. of coal is analyzed, and the first heating shows a loss of weight of 1 g., the second of 3 g., the third 5 g., the remainder, or ash,

weighing .1 g., the complete report would be as follows:

	Per Cent. of the Moist Coal.	Per Cent. of the Dry Coal.	Per Cent. of the Combustible.
Moisture Volatile matter Fixed carbon Ash	10 30 50 10	33.33 55.56 11.11	37.50 62.50
Total	100	100.00	100.00

STEAM.

A calculation of the power that coal possesses, compared with the useful work which steam engines exert, shows that probably in the very best engines not one-tenth of the power is converted into useful work, and in some very bad engines, probably not one one-hundredth. There are many causes for this; some we can never remedy, because to do so it would be necessary to exhaust the steam at a lower temperature than is practical. There are other causes that can and ought to be removed. We want good engines, good boilers, high-pressure steam, expansive working, and condensing appliances.

High-Pressure Stesm.—Why should we use high-pressure steam? There are several good reasons. Whatever pressure we have available at the steam boiler, a certain amount is absorbed in overcoming the resistances of the engine and without doing any useful work. Suppose our available steam pressure is 20 lb., and 10 lb. are so absorbed; that leaves us only one-half; but, if we have 100 lb. available, it would leave us nine-tenths. High-pressure steam means fewer boilers and smaller engines, with foundations and houses of less dimensions. Then, again, the amount of work that it is possible to get out of a given quantity of steam depends on the difference between the temperature at the commencement of the stroke and the temperature at the end of the stroke.

Now, there is a limit as to how low the temperature can be at the end, and as we raise the commencing temperature, we enlarge the available difference. We may put the advantages of high-pressure steam in this way. By taking a fixed temperature in the condenser of, say, 100° F., and initial temperatures when the steam enters the cylinder, of varying amounts, the theoretic efficiency of that steam can be determined. Commencing with

atmospheric pressure, we have an efficiency of 16.6%.

Lb.	Per Cent.		Per Cent.
10			29.8
20			31.1
30			32.2
	25.0		33.9
50	26.1		35.3
	28.6	300	36.5
80	20.0		

176 BOILERS.

We can only get in practice with steam a certain proportion of the

We can only get in practice with steam a certain proportion of the theoretic power, and that proportion varies with the pressure of the steam. In early days we used steam at atmospheric pressure, the efficiency being 16.6%; afterwards, we had, in compound engines of two cylinders, steam of 60 lb., the efficiency being 27%. Now we have triple-expansion engines, using steam at 150 lb., the efficiency being 32.2%. It will be observed that, although the efficiency increases as the steam pressure increases, the amount of that increase is a diminishing quantity, and it becomes so small at and beyond 150 lb. pressure that probably any gain in efficiency is not a satisfactory set-off to the additional expense of strengthening the parts of the engine. But then, how very few of our engines work nearly so high as 150 lb pressure. nearly so high as 150 lb. pressure.

The advantages of high-pressure steam are not yet sufficiently appreciated. It is not merely the difference between 60 lb. and 120 lb. Suppose we use steam at 60 lb.; probably we shall get 50 lb. at engine, and resistances of engine will absorb 10 lb., leaving 40 lb. Now, suppose we use 120 lb., we can get at engine 110 lb., and if resistances of engine absorb 10 lb., we shall have

100 lb. as against 40 lb.

Expansion of Steam.—By "expansion of steam" we mean that at a certain point of the stroke we shut off steam supply from the boiler to the cylinder, and the steam already within the cylinder performs the remainder of the stroke unaided. Now, suppose we do not expand at all. Suppose we allow free admission of steam into the cylinder all through the stroke; we shall free admission of steam into the cylinder all through the stroke; we shall have at the end of the stroke pressure exactly similar to the pressure with which we commenced. Now, we cannot work a seam of coal and still have the coal left; we cannot get work out of steam and still have the work left in it, and so, if our steam pressure is the same at the end of the stroke as at the beginning, we simply discharge twice in each revolution a whole cylinder full of steam that has done no work at all, and waste it just the same as if we had discharged it from the boiler without passing through the engine at all. But some one will say, work has been done upon the engine while that steam was in the cylinder. True—and the explanation is, that while the steam is performing work its heat and pressure must diminish, and so long as the communication with the boiler is open, fresh heat comes from the boiler into the cylinder to take its place, and at the end of the from the boiler into the cylinder to take its place, and at the end of the stroke we have expended heat represented by the capacity of two cylinders, and have performed work as represented by the capacity of one cylinder. Now, suppose we close the communication, and beyond a certain point of the stroke allow no more steam to enter, we get an amount of work from the steam already in the cylinder, represented by the diminishing pressure of the steam by expansion.

Condensers.—The effective power of an engine does not depend on, and is not measured by, the pressure pushing the piston. There is always what is termed a back pressure holding the piston back, and the real effective pressure is evidently the difference between the two. Suppose we have a locomotive engine, or a winding engine, throwing exhaust into the open air. The back pressure cannot be less than the pressure of the open air, and, indeed, to overcome it, it must be something more. But if we can discharge our exhaust into some vessel from which atmospheric pressure and all other pressure has been removed, we know that atmospheric pressure amounts to about 15 lb., and the removal of that from the front of the piston is as good as adding 15 lb. behind.

BOILERS.

The steam boiler that will be the most suitable for a certain mine will The steam boller that will be the most suitable for a certain inne will depend on the nature of the feedwater, the cost of fuel, and the amount of steam required. When the acid water from the mine is used for feedwater, and fuel is cheap, the type of boiler generally used is either the plain cylindrical or flue boiler, because it is simple in construction and can therefore be easily cleaned and cheaply replaced when eaten by the mine water. The tubular or locomotive type is used where good water can be obtained, except in the best equipped piants, where the water-tube boiler is used. Feedwater taken from the mine, or containing acid, should be neutralized by lime or soda before being used. In case it contains minerals in solution, a feedwater separator should be employed to precipitate the mineral substance before the water is allowed to enter the boiler.

We always calculate the strength of a boiler in the direction of its diameter, because, theoretically, a boiler is twice as strong in the direction of length as direction of diameter. Many causes may bring about boiler explosions. First, bad materials; second, bad workmanship; third, bad water, which eats away the plates by internal corrosion; fourth, water lying upon plates, bringing about external corrosion; fifth, overpressure; sixth, safety valves sticking; seventh, water getting too low; eighth, excessive firing; ninth, hot gases acting on plates above water level; tenth, choking of friedpipes; eleventh, insufficient provision for expansion and contraction; twelfth, insufficient steam room and too sudden a withdrawal of a large quantity of steam; thirteenth, getting up steam, or knocking off a boiler too suddenly; fourteenth, allowing wet ashes to lie in contact with plates. The probable causes suggest their several remedies.

Wherever possible, and except under certain circumstances, steam engines should not be placed in the mine, and certainly steam boilers should be in all cases placed upon the surface. Steam injures the ventilation, increasing the temperature where already too high, doing injury and causing inconvenience by condensation, and many fires in mines have been

caused by underground boilers.

The Lancashire Boiler, -The colliery boiler that finds much favor in England is that class of Lancashire boiler which is 28 or 30 ft. long and 7 or 8 ft. in diameter, and has two large flues running through. There is no doubt that the marine type will generate more steam with a given amount of coal, and, consequently, is gaining ground, and will gain ground where coal is dear. But the Lancashire boiler is a good steam generator, and will not only work longer without repairs, but is less troublesome and expensive to repair. The favorite construction some few years ago was wrought iron with double-riveted horizontal joints and Galloway tubes (Galloway tubes are simply taper tubes running across the flues in the boiler), and expansion weldless hoops strengthening the flues and allowing for expansion and contraction. The dimensions were 7 ft. diameter, and from 28 to 30 ft. long, with internal flues each 2 ft. 9 in. diameter, the circular plates being about \$\frac{1}{4}\$ in, and the end plates about \$\frac{1}{4}\$ in. The safe working pressure was about \$60 lb. per sq. in. Now the conditions are somewhat altered. Steel has taken the place of iron, giving increased strength, and allowing increased diameter and increased pressure. Ring plates have also abolished a great source of weakness in a boiler, namely, horizontally riveted joints. A good Lancashire boiler now will measure 8 ft. in diameter and 30 ft. long, with ring plates \(\frac{1}{2}\) in. thick, end plates probably \(\frac{3}{2}\) in., and will work very well at 120 lb. pressure per sq. in.

Horsepower of Boilers.—The horsepower of a boiler is a measure of its capacity for generating steam. Boilernwhere squally rate the horsepower.

capacity for generating steam. Boilermakers usually rate the horsepower of their boilers as a certain fraction of the heating surface; but this is a very indefinite method, for with the same heating surface, different boilers of the same type may, under different circumstances, generate different quantities of steam.

In order to have an accurate standard of boiler power, the American In order to have an accurate standard of botter power the american Society of Mechanical Engineers has adopted as a standard horsepower an evaporation of 30 lb. of water per hour from a feedwater temperature of 100° F. into steam at 70 lb. gauge pressure, which is considered equivalent to 34.5 units of evaporation; that is, to 34.5 lb. of water evaporated from a feedwater temperature of 212° F. into steam at the same temperature. Example.—A boiler evaporates per hour 1,980 lb. of water from a feed temperature of 100° into steam at 70 lb. gauge pressure. What is the

horsepower of the boiler?

Since, under the given conditions, an evaporation of 30 lb. is equivalent to 1 horsepower, the number of horsepower is $1.980 \div 30 = 66$.

In the various types of boilers there is a nearly constant ratio between the water-heating surface and the horsepower, and also between the heating surface and the grate area. These ratios are given in the table on page 178.

If the heating surface of a boiler is known, the horsepower can be found roughly; thus, if a return-tubular boiler has a heating surface of 900 sq. ft., its horsepower lies between $\frac{900}{10} = 50$ H. P. and $\frac{900}{10} = 64.3$ H. P., say about 57 H. P.

The heating surface of a boiler is the portion of the surface exposed to the action of flames and hot gases. This includes, in the case of the multi-tubular boiler, the portions of the shell below the line of brickwork, the exposed heads of the shell, and the interior surface of the tubes. In

case of a water-tube boiler, the heating surface comprises the portion of the shell below the brickwork, the outer surface of the headers, and outer surface of tubes. In any given case, the heating surface may be calculated

RATIO OF HEATING SURFACE TO HORSEPOWER AND OF HEATING SURFACE TO GRATE AREA.

Type of Boiler.	$Ratio = \frac{Heating Surface}{Horsepower}.$	Ratio = $\frac{\text{Heating Surface}}{\text{Grate Area}}$.
Plain cylindrical Flue	6 to 10 8 to 12 14 to 18 15 to 20 10 to 12 1 to 2	12 to 15 20 to 25 25 to 35 25 to 30 35 to 40 50 to 100

by the rules of mensuration. The following example will show the method

of calculating the heating surface of a return-tubular boiler:

EXAMPLE.—A horizontal return-tubular boiler has the following dimen-

sions: Diameter, 60 in.; length of tubes, 12 ft.; internal diameter of tubes, 3 in.; number of tubes, 82. Assume that 1 of the shell is in contact with hot gases or flame, and 1 of the two heads are heating surface.

Circumference of shell = 60 × 3.1416 = 188.496 = 188.5 in., say.

 $= 60 \times 3.1416 = 188.496 = 188.5 \text{ in., say.}$ = $12 \times 12 = 144 \text{ in.}$ Length of shell

= $188.5 \times 144 \times 1 = 18,096$ sq. in. = $3 \times 3.1416 = 9.425$ in., nearly. Heating surface of shell Circumference of tube

 $= 82 \times 144 \times 9.425 = 111,290.4 \text{ sq. in.}$ Heating surface of tubes Area of one head

Two-thirds area of both heads $= 60^{\circ} \times .7854 = 2.827.44 \text{ sq. in.}$ Two-thirds area of both heads $= 1 \times 2 \times 2.827.44 = 3.769.92 \text{ sq. in.}$ From the heads must be subtracted twice the area cut out by the tubes;

From the neans must be subsected this is $82 \times 3^2 \times .7854 \times 2 = 1,159.26$.

Total heating surface in square feet = 18,096 + 111,290.4 + 3,769.92 - 1,159.26 = 916.64 sq. ft. Ans. 144

PROBABLE MAXIMUM WORK OF A PLAIN CYLINDRICAL BOILER OF 120 SQ. FT. HEATING SURFACE AND 12 SQ. FT. GRATE SURFACE, AT DIFFERENT RATES OF DRIVING.

Rate of driving; lb. water evaporated per sq. ft. of heating surface per hour Total water evapora-	2	3	3.5	4	4.5	5	6	7	8
ted by 120 sq. ft. heating surface per									
hour, lb		360.00	420.00	480.00	540.00	600.00	720.00	840.00	960.00
Horsepower; 34.5 lb. per hour = 1 H. P.		10.43	12.17	13.91	15.65	17.39	20.87	24.35	27.83
Pounds water evapo-				1000			1111111	100,000	Chester C
rated per lb. com-		100		2000					2302
bustible	10.88	11.30	11.36	11.29	11.20	11.05	10.48	9.48	8.22
Pounds combustible								122000	W
burned per hour		31.90	37.00	42.50	48.20	54.30	68.70	88.60	116.80
Pounds combustible		1						1	COSTA TO
per hour per sq. ft.		0.05	0.00	0.00	1.00	1 =0			
of grate	1.85	2.65	3.08	3.55	4.02	4.52	5.72	7.38	9.73
Pounds combustible							101	1000	100
per hour per horse-		0.05	001	0.00	0.00	0.10	0.00	0.01	
power	3.17	3.05	3.04	3.06	3.08	3.12	3.30	3.64	4.16

From the figures in the last line, we see that the amount of fuel required for a given horsepower is nearly 37% greater when the rate of evaporation is 8 lb. than when it is 3.5 lb.

The figures in the preceding table that represent the economy of fuel, viz., "Pounds water evaporated per ib combustible" and "Pounds combustible per hour per horsepower," are what may be called "maximum" results, and they are the highest that are likely to be obtained with anthracite coal, with the most skilful firing and with every other condition most favorable. Unfavorable conditions, such as poor firing, scale on the inside of the heating surface, dust or soot on the outside, imperfect protection of the top of the boiler from radiation, leaks of air through the brickwork, or leaks of water through the blow-off pipe, may greatly reduce these figures.

Choice of a Boller.—Questions that arise under this head in regard to any

boiler are:

1. Is the grate surface sufficient for burning the maximum quantity of coal expected to be used at any time, taking into consideration the available draft, the quality of the coal, its percentage of ash, whether or not the ash tends to run into clinker, and the facilities, such as shaking grates, for getting rid of the ash or clinker?

2. Is the furnace of a kind adapted to burn the particular kind of coal

used?

3. Is the heating surface of extent sufficient to absorb so much of the heat generated that the gases escaping into the chimney shall be reasonably low in temperature, say not over 450° F. with anthracite, and 550° F. with bituminous coal?

4. Are the gas passages so designed and arranged as to compel the gas to traverse at a uniform rate the whole of the heating surface, being not so large at any point as to allow of the gas finding a path of least resistance, or short-circuiting, or, on the other hand, so contracted at any point as to

cause an obstruction to the draft?

These questions being settled in favor of any given boiler—and they may be answered favorably for boilers of many of the common types—the relative merits of the different types may now be considered with reference to their danger of explosion; their probable durability; the character and extent of repairs that may be needed from time to time, and the difficulty, delay, and expense that these may entail; the accessibility of every part of the boiler to inspection, internal and external; the facility for removal of mud and scale from every portion of the inner surface, and of dust and soot from the exterior; the water and steam capacity; the steadiness of water level, and the arrangements for securing dry steam.

Each one of the points referred to above should be considered carefully

Each one of the points referred to above should be considered carefully by the intending purchaser of any type of boiler with which he is not familiar by experience. The several points may be considered more in

detail.

Danger of Explosion.—All boilers may be exploded by overpressure, such as might be caused by the combination of an inattentive fireman and an inoperative safety valve, or by corrosion weakening the boiler to such an extent as to make it unable to resist the regular working pressure; but some boilers are much more liable to explosion than others. In considering the probability of explosion of any boiler of recent design, it is well to study it to discover whether or not it has any of the features that are known to be dangerous in the plain cylinder, the horizontal tubular, the vertical tubular, and the locomotive boilers. The plain cylinder boiler is liable to explosion from strains induced by its method of suspension, and by changes of temperature. Alternate expansion and contraction may produce a line of weakness in one of the rings, which may finally cause an explosion. A boiler should be so suspended that all its parts are free to change their position under changes of temperature without straining any part. The circulation of water in the boiler should be sufficient to keep all parts at nearly the same temperature. Cold feedwater should not be allowed to come in contact with the shell, as this will cause contraction and strain. The horizontal tubular boiler, and all externally-fired shell boilers, are liable to explosion from overheating of the shell, due to accumulation of mud, scale, or grease, on the portion of the shell lying directly over the fire, to a double thickness of iron with rivets, together with some scale, over the fire, or to low water uncovering and exposing an unriveted part of the shell directly to the hot gases. Vertical tubular boilers are liable to explosion from deposit of mud, scale, or grease, upon the lower tube-sheet, and from low water allowing the upper part of the tubes to get hot and cease to act as stays to the upper tube-sheet. Locomotive boilers may explode from leposits of mud, scale, from low water exposing the dry crown sheet

to the hot gases, and from corrosion of the staybolts. Double-cylinder boilers, such as the French elephant boiler, and the boilers used at some American blast furnaces, have exploded on account of the formation of a "steam pocket" on the upper portion of the lower drum, the steam being prevented from escaping from out of the rings of the drum by the lap joint of the adjoining ring, thus making a layer of steam about ½ inch thick against the shell which was directly exposed to the hot gases

of the adjoining ring, thus making a layer of steam about \(\) inch thick against the shell, which was directly exposed to the hot gases.

Questions to Be Asked Concerning New Bollers.—The causes mentioned above are only a few of the causes of explosions, but they are the principal ones that are due to features of design. These features should be looked for in any new style of boiler, and if they are found they should be considered elements of danger. Such questions as the following may be asked: Is the method of suspension of the boiler such as to allow its parts to be free to move under changes of temperature? Is there a shell with riveted seams exposed to the fire? Is there a shell exposed to the fire that may at any time be uncovered by water? Is there a crown sheet on which scale may lodge? Are there vertical or inclined tubes acting as stays to an upper sheet, the upper part of which tubes may become overheated in case of low water? Are there any stayed sheets, the stays of which are liable to become corroded? Is there any chance for a steam pocket to be formed on a sheet that is exposed to the fire?

In addition to the above-mentioned features of design, which are elements of danger, all boilers, as already stated, are liable to explosion due

In addition to the above-mentioned features of design, which are elements of danger, all boilers, as already stated, are liable to explosion due to corrosion. Internal corrosion is usually due to acid feedwater, and all boilers are equally liable to it. External corrosion, however, is more liable to take place in some designs of boilers than others, and in some locations rather than others. If any portion of a boiler is in a cold and damp place, it is liable to rust out. For this reason the mud-drums of many modern forms of boilers are made of cast iron, and resist rusting better than either wrought iron or steel. If any part of a boiler, other than a part made of cast iron, is liable to be exposed to a cold and damp atmosphere, or covered with damp soot or ashes, or exposed to drip from rain or from leaky pipes, and especially if such part is hidden by brickwork or otherwise so that it can-

not be seen, that part is an element of danger.

Durability.—The question of durability is partly covered by that of danger of explosion, which has already been discussed, but it also is related to the question of incrustation and scale. The plates and tubes of a boiler may be destroyed by internal or external corrosion, but they may also be burned out. It may be regarded as impossible to burn a plate or tube of iron or steel, no matter how high the temperature of the flame, provided one side of the metal is covered with water. If a steam pocket is formed, so that the water does not touch the metal, or if there is a layer of grease or hard scale, then the plate or tube may be burned. In a water tube that is horizontal, or nearly so, and in which the circulation of water is defective, it is possible to form a mass of steam that will drive the water away from the metal, and thus allow the tube to burn out. In considering the probable durability of a boiler, we may ask the same questions as those that have been asked concerning danger of explosion. There are, however, many chances of a disastrous explosion. Thus the tubes of a water-tube boiler, if allowed to become thickly covered with scale, might be burned out again and again without causing any further destruction at any one time than the rupture of a single tube. A new type of boiler should be questioned in regard to the likelihood of frequent small repairs being necessary, as well as in regard to its liability to complete destruction. We may ask: Is the circulation through all parts of the boiler such that the water cannot be driven out of any tube or from any portion of a plate, so as to form a steam pocket exposed to high temperature? Are there proper facilities for removing the scale from every portion of the plates and tubes?

Repairs.—The questions of durability and of repairs are, in some respects, related to each other. The more infrequent and the less extensive the repairs, the greater the durability. The tubes of a boiler, where corroded or burnt out, may be replaced and made as good as new. The shell, when it springs a leak, may be patched, and is then likely to be far from as good as new. When the shell corrodes badly it must be replaced, and to replace the shell is the same as getting a new boiler. Herein is the advantage of the sectional water-tube boilers. The sections, or parts of a section, may be

renewed easily, and made as good as new, while the shell, being far removed continuous the fire and easily kept dry externally, is not liable either to burning out or external corrosion. In considering the merits of a new style of boiler, with reference to repairs, we may ask whe, parts of the boiler are most likely to give out and need to be repaired or replaced? Are these repairs easily effected, how long will they require, and, after they are made, it is the bellier expendent out.

Is the boiler as good as new?

Facility for Removal of Scale and for inspection.—These questions have already been discussed to some extent under the head of durability. Some water-tube boilers, now dead and gone, were some years ago put on the market, which had no facilities for the removal of scale. It was claimed by their promoters that they did not need any, because their circulation was so rapid. Every few years boilers of these types are reinvented, and the same claim is made for them, that their rapid circulation prevents the formation The fact is that if there is scale-forming material in the water it will be deposited when the water is evaporated, and no amount or kind of circulation will keep it from accumulating on every part of the boiler, and in every kind of tubes, vertical, horizontal, and inclined. I have seen the nearly vertical circulating tubes of a water-tube boiler, in which the circulation is nine times as fast as the average circulation in the inclined tubes, nearly full of scale; that is, a 4" tube had an opening in it of less than 1 in. in diameter. This was due to carelessness in blowing off the boiler, or exceptionally bad feedwater, or both. If circulation would prevent scaling at all, it would prevent it here.

Water and Steam Capacity.—It is claimed for some forms of boilers that they are better than others because they have a larger water or steam capacity. Great water capacity is useful where the demands for steam are extremely fluctuating, as in a rolling mill or a sugar refinery, where it is desirable to store up heat in the water in the boilers during the periods of the least demand, to be given out during periods of greatest demand. Large water capacity is objectionable in boilers for factories, usually, especially if they do not run at night, and the boilers are cooled down, because there is a large quantity of water to be heated before starting each morning. If "rapid steaming" or the ability to get up steam quickly from cold water, or to raise the pressure quickly, is desired, large water capacity is a detriment. The advantage of large steam capacity is usually overrated. It is useful to enable the steam to be drained from water before it escapes into the steam pipe, but the same result can be effected by means of a dry pipe, as in locomotive and marine practice, in which the steam space in the boiler is very small in proportion to the horsepower. Large steam space in the boiler is of no importance for storing energy or equalizing the pressure during the stroke of an engine. The water in the boiler is the place to store heat, and if the steam pipe leading to an engine is of such small capacity that it reduces the pressure, the remedy is a steam reservoir close to the engine or a large steam pipe.

Steadiness of Water Level.—This requires either a large area of water surface, so that the level may be changed slowly by fluctuations in the demand for steam or in the delivery of the feed-pump, or else constant, and preferably automatic, regulation of the feedwater supply to suit the steam demand. A rapidly lowering water level is apt to expose dry sheets or tubes to the action of the hot gases, and thus be a source of danger. A rapidly rising level may, before it is seen by the fireman, cause water to be carried over

into the steam pipe, and endanger the engine.

Water Circulation.—Positive and complete circulation of the water in a boiler is important for two reasons: (1) To keep all parts of the boiler of a uniform temperature, and (2) to prevent the adhesion of steam bubbles to the surface, which may cause overheating of the metal. It is claimed by some manufacturers that the rapid circulation of water in their boilers tends to make them more economical than others. I have as yet, however, to find any proof that increased rapidity of circulation of water beyond that usually found in any boiler will give increased economy. We know that increased rate of flow of air over radiating surfaces increases the amount of heat transmitted through the surface, but this is because by the increased circulation, cold air is continually brought into contact with the surface, making an increased difference of temperature on the two sides, which causes increased transmission. But by increasing the rapidity of circulation in a steam boiler we cannot vary the difference of temperature to any appreciable extent, for the water and the steam in the boiler are at about the same temperature throughout. The ordinary or "Scotch" form of marine boiler shows an exception to the general rule of uniformity of temperature of water throughout the boiler, but the temperature above the level of the lower fire tubes is practically uniform.

INCRUSTATION AND SCALE.

Nearly all waters contain foreign substances in a greater or less degree, Nearly all waters contain foreign substances in a greater or less degree, and though this may be a small amount in each gallon, it becomes of importance where large quantities are evaporated. For instance, a 100 H. P. boller evaporates 30,000 lb. of water in 10 hours, or 390 tons per month; in comparatively pure water there would be 88 lb. of solid matter in that quantity, and in many kinds of spring water as much as 2,000 lb.

The nature and hardness of the scale formed of this matter will depend on the kind of substances held in solution and suspension. Analyses of a great variety of incrustations show that carbonate and sulphate of lime form the larger part of all ordinary scale, that from carbonate being soft and granular, and that from sulphate, hard and crystalline. Organic substances in connection with carbonate of lime will also make a hard and troublesome scale.

troublesome scale.

The presence of scale or sediment in a boiler results in loss of fuel, burning and cracking of the boiler, predisposes to explosion, and leads to extensive repairs. It is estimated that the presence of 13% of fuel; \(\frac{1}{2}\) in., 38%; and \(\frac{1}{2}\) in. 66%. The Railway Master Mechanics' Association of the United States estimates that the loss of fuel, extra repairs, etc., due to incrustation, amount to an average of \$750 per annum for every locomotive in the Middle and Western States, and it must be nearly the same for the same power in stationary boilers.

Causes of Incrustation.-

Deposition of suspended matter.

Deposition of salts from concentration.

Deposition of carbonates of lime and magnesia, by boiling off carbonic acid, which holds them in solution.

4. Deposition of sulphates of lime, because sulphate of lime is soluble in cold water, less soluble in hot water, insoluble above 270° F.

Deposit of magnesia, because magnesium salts decompose at high temperatures. 6. Deposition of lime soap, iron soap, etc., formed by saponification of grease.

Method of Preventing Incrustation.-

Filtration. Blowing off.

- Use of internal collecting apparatus, or devices, for directing the 3. circulation.
 - Heating feedwater. 4.
 - 5. Chemical or other treatment of water in boiler.
 - Introduction of zinc in boiler.
 - Chemical treatment of water outside of boiler.

• Troublesome Substance.	Trouble.	Remedy or Palliation.
Sediment, mud, clay, etc. Readily soluble saits.	Incrustation.	Filtration; blowing off. Blowing off.
Bicarbonates of lime, magnesia, and iron.	Incrustation.	Heating feed; addition of caustic soda, lime, or magnesia, etc.
Sulphate of lime.	Incrustation.	Addition of carbonate of soda, barium chloride, etc.
Chloride and sulphate of magnesium. Carbonate of soda in large amounts. Acid (in mine water).	Corrosion. Priming. Corrosion.	Addition of carbonate soda, etc. Addition of barium chloride, etc. Alkali.
Dissolved carbonic acid and oxygen.	Corresion.	Heating feed; addition of caustic soda, slaked lime, etc.
Grease (from condensed water).	Corresion.	Slaked lime and filtering. Substitute
Organic matter (sewage).	Priming.	Precipitate with alum or ferric chloride, and filter.
Organic matter.	Corresion.	Precipitate with alum or ferric chloride, and filter.

Means of Prevention.—It is absolutely essential to the successful use of any boiler, except in pure water, that it be accessible for the removal of scale, for though a rapid circulation of water will delay the deposit, and certain chemicals will change its character, yet the most certain cure is periodical inspection and mechanical cleaning. This may, however, be rendered less frequently necessary, and the use of very bad water more practical by the employment of some preventives. The following are fair samples of those in use, with their results:

M. Bidard's observations show that "anti-incrustators" containing organic matter help rather than hinder incrustations, and are therefore

to be avoided.

Oak, hemlock, and other barks and woods, sumac, catechu, logwood, etc. are effective in waters containing carbonates of lime or magnesia, by reason of their tannic acid, but are injurious to the iron and not to be recom-

mended.

Molasses, cane juice, vinegar, fruits, distillery slops, etc. have been used with success so far as scale is concerned, by reason of the acetic acid that they contain, but this is even more injurious to the iron than tannic acid, while the organic matter forms a scale with sulphate of lime when it is present.

Milk of lime and metallic zinc have been used with success in waters charged with bicarbonate of lime, reducing the bicarbonate to the insoluble

carbonate.

Barium chloride and milk of lime are said to be used with good effect at

Krupp's works, in Prussia, for waters impregnated with gypsum.

Soda ash and other alkalies are very useful in waters containing sulphate of lime, by converting it into a carbonate, and so forming a soft scale easily cleaned. But when used in excess they cause foaming, particularly where there is oil coming from the engine, with which they form soap. All soapy substances are objectionable for the same reason.

Petroleum has been much used of late years. It acts best in waters in which sulphate of lime predominates. Sulphate of lime is the injurious substance in nearly all mine waters, and petroleum, when properly prepared, is a good preventive of scale and pitting. Crude petroleum should not be used, as it sometimes helps in forming a very injurious scale. Refined petroleum, on the other hand, is useless, as it vaporizes at a temperature below that of boiling water. Therefore, only such preparations should be used as will not vaporize below 500° F.

Tannate of soda is a good preparation for general use, but in waters containing much sulphate, it should be supplemented by a portion of carbonate

of soda or soda ash.

A decoction from the leaves of the eucalyptus is found to work well in

some waters in California.

For muddy water, particularly if it contain salts of lime, no preventive of incrustation will prevail except filtration, and in almost every instance the use of a filter, either alone or in connection with some means of precipita-

ting the solid matter from solution, will be found very desirable.

In all cases where impure or hard waters are used, frequent "blowing" from the mud-drum is necessary to carry off the accumulated matter, which if allowed to remain would form scale.

When boilers are coated with a hard scale, difficult to remove, it will be found that the addition of \(\frac{1}{2} \) b. caustic soda per horsepower, and steaming for some hours, according to the thickness of the scale, just before cleaning, will greatly facilitate that operation, rendering the scale soft and loose. This should be done, if possible, when the boilers are not otherwise in use.

COVERING FOR BOILERS, STEAM PIPES, ETC.

The losses by radiation from unclothed pipes and vessels containing steam are considerable, and in the case of pipes leading to steam engines, are magnified by the action of the condensed water in the cylinder. fore is important that such pipes should be well protected. The following table gives the loss of heat from steam pipes naked, and clothed with wool or hair felt, of different thickness, the steam pressure being assumed at 75 lb.. and the exterior air at 60°.

There is a wide difference in the value of different substances for protection from radiation, their values varying nearly in the reverse ratio to their conducting power for heat, up to their ability to transmit as much heat as the surface of the pipe will radiate, after which they become detrimental, rather than useful, as covering. This point is reached nearly at baked clay or brick.

TABLE OF LOSS OF HEAT FROM STEAM PIPES.

	2 In.	Dian	aeter.	4 In.	Dian	neter.	6 In.	6 In. Diameter.			8 In. Diameter.			. Diam	eter
'			ьег			per		1	Je J			Je L			١.
	i in Units ot Run per Hour.	of Loss.	ngth Lost.	in Units oot Run per Hour.	Ratio of Loss.	ngth ost.	s in Units of Run per Hour.	Ratio of Loss.	Lost.	in Units of Run per Hour.	Ratio of Loss.	ength Lost.	in Units of Run per Hour.	Ratio of Loss.	Length per
	Loss in per Foot Ho	Ratio	Feet in Le H. P.	Loss in per Foot Hot	Ratio	Feet in Le H. P. 1	J 28 in per Foot Ho	Ratio	Feet in I H. P.	Loss in per Foot Ho	Ratio	Feet in L H. P.	Loss in per Foot Hou	Ratio	Feet in L.
	219.0 100.7	1.00	132 288	390.8 180.9	1.00	75 160	624.1	1.000	46	729.8	1.000	40	1,077.4	1.000	21
ı	65.7	.30	441	117.2	.30	247	187.2	.300	154	219.6	.301	132	301.7	.280	9:
Į	43.8	.20	662	73.9	.18	392	111.0	.178	261	128.3	.176	225	185.3	.172	15
į	28.4 19.8	.13	1,020 1,464	44.7 28.1	.11 .07	648 1.031	66.2 41.2	.106	438 703	75.2 46.0	.103	385 630	98.0	.091	29 48
	19.8	.09	1,404	23.4	.06		33.7	.054	860	34.3	.063	845	60.3 45.2	.056	64

A smooth or polished surface is of itself a good protection, polished tin or Russia iron having a ratio, for radiation, of 53 to 100 for cast iron. Mere color makes but little difference.

TABLE OF CONDUCTING POWER OF VARIOUS SUBSTANCES.
(From Péclet.)

Substance.	Conducting Power.	Substance.	Conducting Power.
Blotting paper Eiderdown Cotton or Wool, any density Hemp, canvas Mahogany dust Wood ashes Straw Charcoal powder	.274 .314 .323 .418 .523 .531 .563 .636	Wood, across fiber Cork Coke, pulverized India rubber Wood, with fiber Plaster of Paris Baked clay Glass Stone	.83 1.15 1.29 1.37 1.40 3.86 4.83 6.60 13.68

Hair or wool felt has the disadvantage of becoming soon charred from the heat of steam at high pressure, and sometimes of taking fire therefrom. This has led to a variety of "cements" for covering pipes—composed generally of clay mixed with different substances, as asbestos, paper fiber, charcoal, etc. A series of careful experiments, made at the Massachusetts Institute of Technology in 1871, showed the condensation of steam in a pipe covered by one of them, as compared with a naked pipe, and one clothed with hair felt, was 100 for the naked pipe, 67 for the "cement" covering, and 27 for the hair felt.

The presence of sulphur in the best coverings and its recognized injurious effects make it imperative that moisture be kept from the coverings for, if present, it will surely combine with the sulphur, thus making it active. Stated in other words, keep the pipes and coverings in good repair. Much of the inefficiency of coverings is due to the lack of attention given them they are often seen hanging loosely from the pipe which they are supposed

to protect.

Table of Relative Value of Non-Conductors. • (From Chas. E. Emery, Ph. D.)

Non-Conductor.	Value.	Non-Conductor.	Value.
Wool felt Mineral wool No. 2 Mineral with tar. Sawdust Mineral wool No. 1 Charcoal Pine wood across fiber.	1.000 .832 .715 .680 .676 .632	Loam, dry and open Slaked lime Gas-house carbon Asbestos Coal ashes Coke in lumps Air space undivided	.550 .480 .470 .363 .345 .277 .136

Carbonate of magnesia, as compared with wool felt at 1.000, has a relative value of .472. This is determined from tests by Prof. Ordway, of Boston, and adjusted to results shown in Prof. Emery's tests.

"Mineral wool," a fibrous material made from blast-furnace slag, is a

good protection, and is incombustible.

Cork chips, cemented together with water glass, make one of the best

coverings known.

A cheap jacketing for steam pipes, but a very efficient one, may be applied as follows: First, wrap the pipe in asbestos paper, though this may be dispensed with; then lay slips of wood lengthways, from 6 to 12, according to size of pipe, binding them in position with wire or cord, and around the framework thus constructed wrap roofing paper, fastening it by paste or twine. For flanged pipe, space may be left for access to the bolts, which space should be filled with felt. If exposed to weather, use tarred paper, or paint the exterior. A French plan is to cover the surface with a rough flour paste, mixed with sawdust until it forms a moderately stiff dough. Apply with a trowel in layers of about \(\frac{1}{2}\) in thick; give 4 or 5 layers in all. If iron surfaces are well cleaned from grease, the adhesion is perfect. For copper, first apply a hot solution of clay in water. A coating of tar renders the composition impervious to the weather.

DATA FOR PROPORTIONING AN ECONOMIZER.

(The Green Fuel Economizer Co., Matteawan, N. Y.)

The following estimate is given for the amount of heating surface to be provided in an economizer to be used in connection with a given amount of boilers:

By allowing 4 sq. ft. of heating surface per boiler horsepower (Centennial rating, 344 lb. of water evaporated from and at 212° = 1 H. P.), we are able to raise the feedwater 60° for every 100° reduction in the temperature entering the economizer with gases from 450° to 600°. These results are cor-

roborated by Mr. Barrus's tests.

With the temperature of the gases entering the economizer at 600° to 700°, we have allowed 44 to 5 sq. ft. of heating surface per boiler horsepower, and for every 100° reduction of gases we have obtained about 65° rise in temperature of the water; the temperature of the feedwater entering averaging from 60° to 120°.

With 5,000 sq. ft. of boiler heating surface (plain cylinder boilers) developing 1,000 H. P., we should recommend using 5 sq. ft. of economizer heating surface per B. H. P., or an economizer of about 500 tubes, and it should heat the feedwater about 300°.

CARE OF BOILERS.

1. Safety Valves.—Great care should be exercised to see that these valves are ample in size and in working order. Overloading or neglect frequently leads to the most disastrous results. Safety valves should be tried at least once every day, to see that they act freely.

once every day, to see that they act freely.

2. Pressure Gauge.—The steam gauge should stand at zero when the pressure is off, and it should show same pressure as the safety valve when that is blowing off. If not, then one is wrong, and the gauge should be

tested by one known to be correct.

Water Level.—The first duty of an engineer before starting, or at the beginning of his watch, is to see that the water is at the proper height. Do not rely on glass gauges, floats, or water alarms, but try the gauge-cocks. If they do not agree with water gauge, learn the cause and correct it.

Gauge-cocks and water gauges must be kept clean. Water gauges should be blown out frequently, and the glasses and passages to them kept clean. The Manchester, England, Boiler Association attributes more accidents to

inattention to water gauges than to all other causes put together.

Feed-Pump or injector.—These should be kept in perfect order, and be of ample size. No make of pump can be expected to be continuously reliable without regular and careful attention. It is always safe to have two means of feeding a boiler. Check-valves and self-acting feed-valves should be frequently examined and cleaned. Satisfy yourself frequently that the valve is acting when the feed-pump is at work.

ashes (wet if possible) or any earth that may be at hand. If nothing else is handy, use fresh coal. Draw fire as soon as it can be done without increasing the heat. Neither turn on the feed, start nor stop engine, nor lift safety valve until fires are out and the boiler cooled down.

Blisters and Cracks.—These are liable to occur in the best plate iron. When the first indication appears, there must be no delay in having it carefully examined and properly cared for.

8. Fusible plugs, when used, must be examined when the boiler is cleaned. and carefully scraped clean on both the water and fire sides, or they are

liable not to act.

9. Firing.—Fire evenly and regularly, a little at a time. Moderately thick fires are most economical, but thin firing must be used where the draft is poor. Take care to keep grates evenly covered, and allow no air holes in the fire. Do not "clean" fires oftener than necessary. With bituminous coal, a "coking fire," i.e., firing in front and shoving back when coked, gives best results if properly managed.

10. Cleaning.—All heating surfaces must be kept clean outside and in, or there will be a serious waste of fuel. The frequency of cleaning will depend on the nature of fuel and water. When a new feedwater supply is introduced, its effect upon the boiler should be closely observed, as this new supply may be either an advantage or a detriment as compared with the working of the boiler previous to its introduction. As a rule, never allow over 4, scale or soot to collect on surfaces between cleanings. Handholes should be frequently removed and surfaces examined, particularly in case of a new boiler, until proper intervals have been established by experience.

The exterior of tubes can be kept clean by the use of blowing pipe and hose through openings provided for that purpose. In using smoky fuel, it is

best to occasionally brush the surfaces when steam is off.

Hot Feedwater.-Cold water should never be fed into any boiler when it can be avoided, but when necessary it should be caused to mix with the heated water before coming in contact with any portion of the boiler.

12. Foaming.-When foaming occurs in a boiler, checking the outflow of steam will usually stop it. If caused by dirty water, blowing down and pumping up will generally cure it. In cases of violent foaming, check the draft and fires.

Air Leaks.—Be sure that all openings for admission of air to boiler or flues, except through the fire, are carefully stopped. This is frequently an

unsuspected cause of serious waste.

14. Blowing Off.—If feedwater is muddy or salt, blow off a portion frequently, according to condition of water. Empty the boiler every week or two, and fill up afresh. When surface blow cocks are used, they should be often opened for a few minutes at a time. Make sure no water is escaping from the blow-off cock when it is supposed to be closed. Blow-off cocks and check-valves should be examined every time the boiler is cleaned. Never empty the boiler while the brickwork is hot.

15. Leaks.—When leaks are discovered, they should be repaired as soon

as possible.

16. Filling Up.-Never pump cold water into a hot boiler. Many times and, in shell boilers, serious weaknesses, and sometimes explosions are the result of such an action.

Dampness.—Take care that no water comes in contact with the exterior of the boiler from any cause, as it tends to corrode and weaken the boiler. Beware of all dampness in seatings and coverings.

Galvanic Action.—Examine frequently parts in contact with copper or brass, where water is present, for signs of corrosion. If water is salt or acid, some metallic zinc placed in the boiler will usually prevent corrosion, but it will need attention and renewal from time to time.

19. Rapid Firing.—In boilers with thick plates or seams exposed to the fire, steam should be raised slowly, and rapid or intense firing avoided. With thin water tubes, however, and adequate water circulation, no dam-

age can come from that cause.

20. Standing Unused.—If a boiler is not required for some time, empty and dry it thoroughly. If this is impracticable, fill it quite full of water, and put in a quantity of common washing soda. External parts exposed to damp-

nh a quantity of common washing some. Executar parts exposed to analyness should receive a coating of linesed oil.

21. Repair of Coverings.—All coverings should be looked after at least once a year, given necessary repairs, refitted to the pipe, and the spaces due to shrinkage taken up. Little can be expected from the best non-conductors if they are allowed to become saturated with water, or if air-currents are permitted to circulate between them and the pipe.

22. General Cleanliness.—All things about the boiler room should be kept clean and in good order. Negligence tends to waste and decay.

THICKNESS OF BOILER IRON REQUIRED AND PRESSURE ALLOWED BY THE LAWS OF THE UNITED STATES.

PRESSURE EQUIVALENT TO THE STANDARD FOR A BOILER 42 IN. IN DIAM-ETER AND 1 IN. THICK.

Thickness.	Diameter.									
16ths.	84 In. Lb.	36 In. Lb.	38 In. Lb.	40 In. Lb.	42 In. Lb.	44 In. Lb.	46 In. Lb.			
5 4 4 3 3 3 3 3	169.9 158.5 135.9 124.5 113.2 101.9	160.4 149.7 128.3 117.6 106.9 96.2	152.0 141.8 121.6 111.4 101.3 91.2	144.4 134.7 115.5 105.9 96.2 82.6	137.5 128.3 110.0 100.8 91.7 82.5	131.2 122.5 105.0 96.2 87.5 78.7	125.5 117.2 100.0 92.0 83.0 75.1			

The rule for finding the proper sectional area for the narrowest part of the nozzle is given by Rankine, S. E., page 477, as follows:

Area in square inches = cubic feet per hour gross feedwater 800 v pressure in atmospheres

Diameter of	Delivery in Gallons per Hour with a Pressure								
Throat. Decimals	per Square Inch of								
of an Inch.	30 Lb.	45 Lb.	60 Lb.	75 Lb.	90 Lb.				
.10	56	69	80	89	98				
.15	127	156	180	201	221				
.20	226	278	321	360	393				
.25	354	434	502	561	615				
.30	505	624	722	807	884				

PRESSURE OF STEAM AT DIFFERENT TEMPERATURES. (Results of Experiments Made by the Franklin Institute.)

Pressure.	Tempera-	Pressure.	Tempera-	Pressure.	Tempera-
Inches of	ture.	Inches of	ture.	Inches of	ture.
Mercury.	Degrees F.	Mercury.	Degrees F.	Mercury.	Degrees F.
30 45 60 75 90 105 120	212.0 235.0 250.0 264.0 275.0 284.0 291.5	135 150 165 180 195 210	298.5 304.5 310.0 315.5 321.0 326.0	225 240 255 270 285 300	331.0 336.0 340.5 345.0 349.0 352.5

MAXIMUM ECONOMY OF PLAIN CYLINDER BOILERS.

	I	ounc	ls of	Wate	r Eva	porat	ed F	om a	nd at	2120.	ě
Per sq. ft. heating surface per hour Per lb. combustible, maximum of other	1.70	2.00	2.60		3.50	4.00	4.50	5.00	6.00	7.00	
boilers, Centennial tests Subtract extra radia-		12.00	12.10	12.05	12.00	11.85	11.70	11.50	10.85	9.80	1
tion loss for cylinder boilers Probable maximum per lb. combus-	1.32	1.12	.87	.75	.64	.56	.50	.45	.37	.32	
tible, cylinder boilers	10.58	10.88	11.23	11.30	11.36	11.29	11.20	11.05	10.48	9.48	

SCHEME FOR BOILER TEST.

1 2 3 4	Number of test Made by Type of boiler. Date of test Duration of test	***-
5		Hr.
•	Dimensions and Proportions.	
6 7	Number of boilers tested	·
	Diameter, boiler	
8	Length, boiler	Ft. In.
10	Width, grate	Ft. In. Ft. In.
11	Length, grate Number of tubes	No.
12		
	Diameter of tubes	
13	Length of tubes Total water heating surface	
14		8q. Ft.
15	Total steam heating surface	Sq. Ft.
16	Grate surface per boiler	Sq. Ft.
17 18	Per cent, air space in grate	9
	Ratio water heating to grate surface	Cla TN
19 20	Area of stack	Sq. Ft.
	Height stack above dead plates	Ft.
21	Ratio stack area to grate surface	
00		7-
22 23	Atmosphere by barometer Steam pressure by gauge	In.
23	steam pressure by gauge	Lb.

SCHEME FOR BOILER TEST-(Continued).

1		!
24	Force chimney draft, inches water	In.
25	Force blast in ash pit, inches water	In.
- 1	Average Temperatures.	İ
26	Of external air	°F.
27	Of fireroom	oF.
28 !	Of steam	oF.
29	Of feedwater before heater	oF.
30	Of feedwater after heater	oF.
31	Of stack gases	oF.
. (Fuel.	
32	Kind of coal	ļ
33	Total coal consumed	Lb.
34	Moisture in coal	56
35	Total dry coal consumed	Lb.
36	Total ash and refuse	Lb.
37	Per cent. ash and refuse in dry coal	
	Total combustible consumed	*
38	CALORIMETRIC TESTS.	Ĺb.
39	Per cent. moisture in steam	4
40	Degrees superheat in steam	°F.
	Water.	
41	Total water pumped into boiler	Lb.
42	Water evaporated corrected for quality of steam	Lb.
43	Equiv. water evap. to dry steam from and at 2120	Lb.
44	Equiv. water evap. to dry steam from and at 212° per hour	Lb.
	Economic Evaporation.	ł
45	Water evap. per lb. dry coal actual pressures and temp	Lb.
46	Equiv. water evap. lb. dry coal from and at 212°	Lb.
47	Equiv. water evap. lb. combustible from and at 2120	Lb.
	Rate of Combustion.	
48	Dry coal burned per hr. per sq. ft. grate surface	Lb.
49	Combustible burned per hr. per sq. ft. grate surface	Lb.
50	Dry coal per hour per H. P. developed	Lb.
•••	Rate of Evaporation,	;
51	Water evan, from and) Per sq. ft. grate surface	Lb.
52	Water evap. from and Per sq. ft. grate surface	Lb.
02	Commercial Horsepower,	2.0.
53	Basis 20 lb. water from 100° feed to 70 lb, steam per hour	Н. Р.
54	Horsepower builders rating	H. P.
55	Heating surface to one horsepower developed	Sq. Ft.
56	Per cent, total horsepower due to feedheater	5q. rt.
90	Tel cent, what noisepower due w reedheater	70

CHIMNEYS.

Chimneys have two important duties to perform, the first being to carry off the waste furnace gases, which requires size, and the second, to produce a draft sufficient to insure the complete combustion of the fuel, which requires height. The area of a chimney is usually made from \$\frac{1}{2}\$ to \$\frac{1}{2}\$ as large as the area of the furnace grates, or of about the same cross-section as the cross-sectional area of the flues or tubes; we have, therefore, a comparatively simple method of determining one of the required dimensions of a chimney, and, when this is known, it becomes an easy matter to determine the height of the chimney when the horsepower of the boiler has been ascertained.

The horsepower of a boiler being given, and the necessary chimney area having been determined, the following rule gives the required height that the chimney must be to produce the necessary draft:

Rule.—From 5.35 times the area of the chimney in square feet, subtract twice the square root of the area of the chimney in square feet, and divide the given horsepower by the remainder. The square of the quotient will be the height of the chimney in feet.

Let
$$\begin{array}{ccc} A & = \text{ area of chimney;} \\ H & = \text{ horsepower of boller;} \\ h & = \text{ height of chimney.} \\ \end{array}$$
 Then,
$$h = \left(\frac{H}{3.33 \ A - 2 \sqrt{A}}\right)^2 .$$

EXAMPLE.—What must be the height of a chimney that is to have a crosssectional area of 7 sq. ft., and to supply the draft for a 141-horsepower boiler?

$$h = \left(\frac{141}{3.33 \times 7 - 2\sqrt{7}}\right)^2 = \left(\frac{141}{3.33 \times 7 - (2 \times 2.65)}\right)^2 = 61.3 \text{ ft.} \text{ Ans.}$$

Forced Draft.—The use of forced draft as a substitute for, or as an aid to, natural chimney draft is becoming quite common in large boiler plants. Its advantages are that it enables a boiler to be driven to its maximum capacity to meet emergencies without reference to the state of the weather or to the character of the coal; that the draft is independent of the temperature of the chimney gases, and that therefore lower flue temperatures may be used than with natural draft; and in many cases that it enables a poorer quality of coal to be used than is required with natural draft. Forced draft may be obtained: First, by a steam jet in the chimney, as in locomotives and steam fire-engines; second, by a steam-jet blower under the grate bars; third, by a fan blower delivering air under the grate bars, the ash-pit doors being closed; fourth, by a fan blower delivering air into a closed fireroom, as in the "closed stoke-hold" system used in some ocean-going vessels; and fifth, by a fan placed in the flue or chimney drawing the gases of combustion from the boilers, commonly called the induced-draft system. Which one of these several systems should be adopted in any special case will usually depend on local conditions. The steam jet has the advantage of lightness and compactness of apparatus, and is therefore most suitable for locomotives and steam fire-engines, but it also is the most wasteful of steam, and therefore should not be used when one of the fan-blower systems is available, except for occasional or temporary use, or when very cheap fuel, such as anthracite culm at the coal mines, is used.

STEAM ENGINES.

What is a Good Steam Engine?—It should be as direct acting as possible: that is, the connecting parts between the piston and the crank-shaft should be few in number, as each part wastes some power. Formerly, beam engines were all the rage. They were well enough in their time for pumpengines were all the rage. They were wen enough in their time for pumping, when the pump was at one end of the beam and the piston at the other. Few of our modern colliery engines have such an appendage, except in some instances for pumping, and even for that kind of work the better engines have no beams. The moving parts of an engine should be strong, to resist strains, and light, so as to offer no undue resistance to motion; parts moving upon each other should be well and truly and smoothly finished, to moving upon each other should be well and truly and smoothly finished, to reduce resistances to a minimum; the steam should get into the cylinder easily at the proper time, and the exhaust should leave the cylinder as exactly and as easily. The steam pipes supplying steam should have an area one-tenth the combined areas of the cylinders they supply, and exhaust pipes should be somewhat larger. The cylinder and the steam pipes and the boiler should be well protected. The engine should be capable of being started and stopped and reversed easily and quickly.

Ruis.—To find the indicated horsepower developed by an engine, multiply together the M. E. P. per square inch, the area of the piston, the length of stroke, and the number of strokes per minute. This gives the work per minute in footpounds. Divide the product by 33,000; the result will be the indicated horsepower of the engine.

power of the engine. Let

N = number of strokes per minute.

Then, the above rule may be expressed thus:

I. H. P. =
$$\frac{P L A N}{33,000}$$
.

The number of strokes per minute is twice the number of revolutions per minute. For example, if an engine runs at a speed of 210 revolutions per minute, it makes 420 strokes per minute. A few types of engines, however, are single acting; that is, the steam acts on only one side of the piston. In this case, only 1 stroke per revolution does work, and, consequently, the number of strokes per minute to be used in the above rule is the same as the number of revolutions per minute.

Example.—The diameter of the piston of an engine is 10 in. and the length of stroke 15 in. It makes 250 revolutions per minute, with a M. E. P. of 40 lb. per sq. in. What is the horsepower?

As it is not stated whether the engine is single or double acting, assume that it is double acting. Then, the number of strokes is $250 \times 2 = 500$ per minute. Hence,

I. H. P.
$$=\frac{PLAN}{33,000}=\frac{40 \times \frac{15}{12} \times (10^2 \times .7854) \times 500}{33,000}=59.5 \text{ H. P.}$$

Γο find the horsepower, the value for the M. E. P. must be substituted for P in the formula I. H. P. $=\frac{PLAN}{N}$ Reducing the stroke to feet, and 33,000

substituting the values of P, L, A, and N, we have

$$\frac{46.92 \times \frac{34}{2} \times (18^{2} \times .7854) \times (200 \times 2)}{33,000} = 241.21 \text{ H. P.} \text{ Ans.}$$

Approximate Determination of M. E. P.—To approximately determine the M. E. P. of an engine, when the point of apparent cut-off is known and the boiler pressure, or the pressure per square inch in the boiler from which the supply of steam is obtained, is given:

Rule.—Add 14.7 to the gauge pressure, and multiply the result by the number opposite the fraction indicating the point of cut-off in the following table. Subtract 17 from the product, and multiply by .9. The result is the M. E. P. for good,

simple non-condensing engines.

Or, letting

p = gauge pressure; k = a constant (see following table);

M. E. P. = mean effective pressure.

M. E. P. = .9[k(p+14.7)-17]. Then.

TABLE.

Cut-Off.	Constant.	Cut-Off.	Constant.	Cut-Off.	Constant.
- Cost-et-ca-	.566 .603 .659 .708 .743	###-4: -\$WG off	.771 .789 .847 .895	##17. ##400. 7##	.917 .926 .937 .944 .951

If the engine is a simple condensing one, subtract the pressure in the condenser instead of 17. The fraction indicating the point of cut-off is obtained by dividing the distance that the piston has traveled when the steam is cut off by the whole length of the stroke. For a $\frac{1}{2}$ cut-off, and 92 lb. gauge pressure in the boiler, the M. E. P. is, by the formula just given, $\frac{9}{2} \cdot \frac{9}{2} \cdot \frac{14}{2} \cdot \frac{7}{2} \cdot \frac{7}{2} = \frac{72}{2} \cdot \frac{6}{2}$ lb. per sq. in. Example.—Find the approximate I. H. P. of a $\frac{9}{2} \cdot \frac{7}{2} \cdot \frac{7}$

boller pressure is 80 lb. gauge. 80 + 14.7 = 94.7. The constant for $\frac{1}{2}$ cut-off is .847, and .847 \times boller pressure = .847 \times 94.7 = 80.21. M. E. P. = (80.21 - 17) \times 9 = 56.89 lb. per sq. in. Then,

I. H. P. =
$$\frac{PL\ A\ N}{33,000} = \frac{56.89 \times \frac{18}{3} \times (.7854 \times 9^2) \times 240 \times 2}{33,000} = 52.64 \text{ H. P. Ans.}$$

RULES FOR ENGINE DRIVERS.

If a gauge glass breaks, turn off the water first and then the steam, to avoid scalding yourself.

Don't buy oil or waste simply because it is very cheap; it will cost more

than a good article in the end.

In cutting rubber for gaskets, etc., have a dish of water handy, and keep

wetting the knife blade; it makes the work much easier.

Don't forget that there is no economy in employing a poor fireman. can, and probably will, waste more coal than would pay the wages of a first-

An ordinary steam engine having two cylinders connected at right angles on the same shaft consumes one-third more steam than a single-cylinder

engine, while developing only the same amount of power.

A fusible plug ought to be renewed every three months, by removing the old metal and refilling the case; and it should be scraped clean and bright on both ends every time that the boiler is washed out, to keep it in good working order.

When you try a gauge-cock, don't jerk it open suddenly, for if the water happens to be a trifle below the cock, the sudden relief from pressure at that point may cause it to lift and flow out, deceiving you in regard to its height. Whereas, if you open it quietly, no lift will occur, and you ascertain surely

whether there is water or steam at that level.

Always open steam stop-valves between boilers very gently, that they may heat and expand gradually. By suddenly turning on steam a stop-valve chest was burst, due to the expansive power of heat unequally applied. The same care is also recommended when shutting off stop-valves. A fearful explosion once occurred by shutting a communicating stop-valve too suddenly-due to the recoil.

In order to obtain the driest possible steam from a boiler, there should be an internal perforated pipe (dry pipe, so called) fixed near the top of the boiler, and suitably connected to the steam pipe. The perforations in this pipe should be from one-quarter to one-half greater in area than that of the steam pipe. Domes are of no use as steam driers; they only add a very little to the steam space of a boiler, and are often a source of loss by radiation

If a glass gauge tube is too long, take a triangular file and wet it; hold the tube in the left hand, with the thumb and forefinger at the place where you wish to cut it, saw it quickly and lightly two or three times with the edge of the file, and it will mark the glass. Now take the tube in both hands, both thumbs being on the side opposite the mark, and an inch or so apart, and then try to bend the glass, using your thumbs as fulcrums, and it will break at the mark, which has weakened the tube.

A stiff charge of coal all over a furnace will lower the temperature 200° After the coal is well ignited the temperature or 300° in a very short time. will rise about 500°, and as it continues burning will gradually drop about 200°, until the fireman puts in another charge, when the sudden fall before mentioned takes place again. This sudden contraction and expansion frequently causes the bursting of a boiler, and it is for this reason that light and frequent charges of coal, or else firing only one-half of the furnace at a time, should be always insisted on.

Be careful when using a wrench on hexagonal nuts that it fits snugly, or

the edges of the nut will soon become rounded.

Be careful how you use a monkeywrench, for if it is not placed on the nut

properly the strain will often bend or fracture the wrench.

The area of grate for a boiler should never be less than \(\frac{1}{2} \) sq. ft. per I. H. P. of the engine, and it is seldom advisable to increase this allowance beyond ‡ sq. ft. per I. H. P.

The area of tube surface for a boiler should not be less than 2‡ sq. ft. per

I. H. P. of the engine.

The ratio of heating surface to grate area in a boiler should be 30 to 1 as a minimum, and may often be increased to 40 to 1, or even more, with advantage

Lap-welded pipe of the same rated size has always the same outside diameter, whether common, extra, or double extra, but the internal diameter is of course decreased with the increased thickness.

A good cement for steam and water joints is made by taking 10 parts, by weight, of white lead, 3 parts of black oxide of manganese, 1 part of litharge.

and mixing them to the proper consistency with boiled linseed oil.

To harden a cutting tool, heat it in a coke fire to a blood-red heat and plunge it into a solution of salt and water (1 lb. of salt to 1 gal. of water), then polish the tool, heat it over gas, or otherwise, until a dark straw and purple mixed color shows on the polish, and cool it in the salt water.

Small articles can be plated with brass by dipping them in a solution of

9; gr. each of sulphate of copper and chloride of tin, in 1; pt. of water.

Don't be eternally tinkering about your engine, but let well enough alone.

Don't forget that with a copper hammer you can drive a key just as well

as with a steel one, and that it doesn't leave any marks.

Keep on hand slips of thin sheet copper, brass, and tin, to use as liners, and if you shape some of them properly, much time will be saved when you need them.

A few wooden skewer pins, such as butchers use, are very useful for

many purposes in an engine room. Try them.

In running a line of steam pipe where there are certain rigid points, make arrangements for expansion on the line between those points, or you will come to grief.

Arrange the usual work of the engine and firerooms systematically, and

adhere to it. It pays well.

Don't forget that cleanliness is next to godliness.

Rubber cloth kept on hand for joints should be rolled up and laid away by itself, as any oil or grease coming in contact with it will cause it to soften

and give out when put to use.

When using a jet condenser, let the engine make three or four revolutions before opening the injection valve, and then open it gradually, letting the engine make several more revolutions before it is opened to the full amount required.

Open the main stop-valve before you start the fires under the boilers. When starting fires, don't forget to close the gauge-cocks and safety valve

as soon as steam begins to form.

An old Turkish towel, cut in two lengthwise, is better than cotton waste

for cleaning brass work.

Always connect your steam valves in such a manner that the valve closes against the constant steam pressure. Turpentine well mixed with black varnish makes a good coating for iron

smoke pipes. Ordinary lubricating oils are not suitable for use in preventing rust.

You can make a hole through glass by covering it with a thin coating of wax, warming the glass and spreading the wax on it. Scrape off the wax where you want the hole, and drop a little fluoric acid on the spot with a wire. The acid will cut a hole through the glass, and you can shape the hole with a copper wire covered with oil and rottenstone.

A mixture of 1 oz. of sulphate of copper, 1 oz. of alum, 1 teaspoonful of powdered salt, 1 gill of vinegar and 20 drops of nitric acid will make a hole in steel that is too hard to cut or file easily. Also, if applied to steel and weehold of suitable, it will give the metal a heautiful frosted appearance.

washed off quickly, it will give the metal a beautiful frosted appearance.

BELTING AND VELOCITY OF PULLEYS.

Belts should not be made tighter than necessary. Over half the trouble from broken pulleys, hot boxes, etc. can be traced to the fault of tight belts, while the machinery wears much more rapidly than when loose belts are employed.

The speed of belts should not be more than 3,000 or 3,750 ft. per minute. The motion of driving should run with and not against the laps of the

Leather belts should be run with the stronger or flesh side on the outside and the grain (hair) side on the inside, nearest the pulley, so that the stronger part of the belt may be subject to the least wear. It will also drive 305 more than if run with the flesh side nearest the pulley. The grain side adheres better because it is smooth. Do not expose leather belts to the weather.

When the length of a belt cannot be conveniently ascertained by measuring around the pulleys with a tape line, the following rule will be serviceable:

Add the diameters of the 2 pulleys together and divide by 2; multiply this quotient by 31, and to the product add twice the distance between the centers of the shafts; the sum will be the length required.

COMPRESSED AIR.*

BY PROF. ROBERT PEELE.

An air compressor consists essentially of a cylinder in which atmospheric air is compressed by a piston, the driving power being steam or water.

Classification of Compressors.—Steam-driven compressors in ordinary use

may be classed as follows:

(a) Straight-line type, in which a single horizontal air cylinder is set tandem with its steam cylinder, and provided with two flywheels. pattern is generally adapted for compressors of small size.

Duplex type, in which there are two steam cylinders, each driving an

air cylinder, and coupled at 90° to a crank-shaft carrying a flywheel. (c) Horizontal, cross-compound engines, each steam cylinder set tandem

with an air cylinder, as in (b).

Vertical, simple, or compound engines, with the air cylinders set

above the steam cylinders. (e) Compound or stage compressors, in which the air cylinders themselves are compounded. The compression is carried to a certain point in one cylinder and successively raised and finally completed to the desired pressure in the others. They may be either of the straight-line or duplex form, with simple or compound steam cylinders.

Classes (a), (b), (c), and (c) are those commonly employed for mine service. The principle of compound, or two-stage, air compression is recognized as applicable for even the moderate pressures required in mining, and the compressors of class (c) are frequently employed.

Construction of Compressors.—Compressors are usually built with a short stroke, as this is conducive to economy in compression as well as the attain-

ment of a proper rotative speed. In ordinary single-stage compressors, the usual ratio of length of stroke to diameter of steam cylinders is 1½ to 1 or 1½ to 1. In some makes, such as the Rand, the ratio is considerably greater, varying from 1½ to 1½ to 1, as in several large plants built for the Calumet & Hecla Mining Co. Many compressors have length and diameter of steam cylinders equal. The relative diameters of the air and steam cylinders depend on the steam pressure carried, and the air pressure to be produced. In mining operations, there is usually but little variation in these conditions. For rock-drill work, the air pressure is generally from 60 to 80 lb.

In using water-power, a compressor is driven most conveniently by a bucket impact wheel, such as the Pelton or Knight. The waterwheel is generally mounted directly on the crank-shaft, without the use of gearing. Since the power developed is uniform throughout the revolution of the wheel, the compressor should be of duplex form, in order to equalize the resistance so far as possible. The rim of the wheel is made extra heavy, to supply the place of a flywheel. When direct-connected, the wheel is of relatively large diameter, as its speed of rotation must of necessity be slow. With small high-speed wheels, the compressor cylinders may be operated through belting or gearing. In most cases, however, the waterwheel may be large enough to render gearing unnecessary. Impact wheels may be employed with quite small heads of water, by introducing multiple nozzles. To prevent the water from splashing over the compressor, the wheel is enclosed in a tight iron or wooden casing. The force of the water is regulated usually by an ordinary gate valve. If the head be great, it may be necessary to introduce means for deflecting the nozzle, so that, when the compressor is to be stopped suddenly, danger of rupturing the water main will be avoided.

Theory of Air Compression.—The useful effect or efficiency of a compressor is the ratio of the force stored in the compressed air to the work that has been expended in compressing it. This probably never reaches 80%, and often

falls below 60%.

^{*}See "Mines and Minerals," Vols. XIX and XX, for complete discussion of this subject by the same author.

Free air is air at ordinary atmospheric pressure as taken into the compressor cylinder. As commonly used, this means air at sea-level pressure (14.7 lb. per sq. in.) at 60° F.

The absolute pressure of air is measured from zero, and is equal to the assumed atmospheric pressure plus gauge pressure. Air-compression calculations depend on the two well-known laws:

1. Boyle's Law.—The temperature being constant, the volume varies inversely as the pressure; or P V = P' V' = a constant; in which V equals volume of given weight of air at the freezing point, and the pressure P; V' equals the volume of the same weight of air at the same temperature and under the pressure P'.

Gay-Lussac's Law.-The volume of a gas under constant pressure, when heated, expands, for each degree of rise in temperature, by a constant proportional part of the volume that it occupied at the freezing point; or, V' = V(1 + a P), in which a equals $\frac{1}{2}$ for centigrade degrees, or $\frac{1}{2}$ for

Fahrenheit degrees.

Theoretically, air may be compressed in two ways, as follows:

1. Isothermally, when the temperature is kept constant during compres-

sion, and in this case, the formula PV = P'V' is true.

Adiabatically, when the temperature is allowed to rise without check during the compression.

Since the pressure rises faster than the volume diminishes, the equation $P \ V = P' \ V'$ no longer holds, and we have $\frac{P'}{P} = \left(\frac{V}{V'}\right)^n$, in which n equals 1.406. The specific heat of air at constant pressure is .2375, and at constant volume .1689, and $n = \frac{.2375}{1000}$

 $\frac{1}{1689} = 1.406.$ In practice, compression is neither isothermal nor adiabatic, but inter-The values of n for different conditions in mediate between the two. practice are as follows, as determined from a 2,000-horsepower stage com-

pressor at Quai de la Gare, Paris.

For purely adiabatic compression, with no cooling arrangements, n=1.406; in ordinary single-cylinder dry compressors, provided with a water-jacket, n is roughly 1.3; while in the best wet compressors (with sprainjection), n becomes 1.2 to 1.25. In the poorest forms of compressor, the value n=1.4 is closely approached. For large, well-designed compressors with compound air cylinders, the exponent n may be as small as 1.15.

Rating of Compressors.—Compressors are rated as follows: (1) In terms of the horsepower developed by the steam end of the compressor, as shown by indicator cards taken when running at full speed, and when the usual volume of air is being consumed. (2) Compressors for mines are often rated roughly as furnishing sufficient air to operate a certain number of rock drills; a 3" drill requires a volume of air at 60 lb, pressure, equal to 100 or 110 cu, ft. of free atmospheric air per minute. (3) In terms of cubic feet of free air compressed per minute to a given pressure.

As the actual capacity of a compressor depends on the density of the intake air, it will obviously be reduced in working at an altitude above sea level, because of the diminished density of the atmosphere. The following

table gives the percentages of output at different elevations:

EXAMPLE.—Calculate the volume of air furnished by an 18" × 24" compressor work-Atmospheric Percentages Altitude. ing at an elevation of 5,000 ft. above sea Pressure. of Output Feet. Pounds. at Sea Level. level, revolving 95 times per minute, and having a piston speed of 380 ft. per minute. $9^2 \times 3.14 = 254.3 \text{ sq. in.} = \text{piston area.}$ 14.7 100.0 1,000 14.2 97.2 \times 380 = 668.8 cu. ft. = volume dis-2,000 13.6 93.5 placed per minute by the piston; deducting 13.1 90.8 3,000 10% for loss gives 602 cu. ft. At sea level at 4,000 12.7 88.4 12.2 85.0 5,000 80 lb. gauge pressure, this equals $\frac{15}{80+15} \times 602 = 95$ cu. ft. At an elevation of 5,000 ft., the output of a compressor would be 82.0 11.7 6.000 7,000 79.3 11.3 8,000 10.9 77.0 9,000 75.0 $95 \times 85\% = 80.7$ cu. ft. per minute. 10.5 10.000 10.1 72.0Cooling.-Compressor cylinders may be

cooled by either of the following methods:

(1) by injecting water into the cylinder, known as wet compressors; or (2) by

jacketing the cylinder in water, known as dry compressors.

Dry Versus Wet Compressors.—Up to about the year 1885 there seemed to be little doubt among mechanical engineers that wet compressors were, on the whole, superior to dry, because, by bringing the air into direct contact with water, the heat is most effectually absorbed. This view is correct, far as heat loss alone is concerned, provided the water in the cylinder is properly applied. But the question of heat loss is not the only consideration. Low first cost and simplicity of construction are often more advantageous than a close approximation to isothermal compression. Latterly, the west system has lost ground, owing to the fact that moisture is objectionable in the air, as it forms frost in the exhaust ports of the drills, and stops them up, and probably no wet compressors are now being built in the United States. In Europe, also, dry compressors have grown in favor, at least for mining plants and others of moderate size.

TRANSMISSION OF AIR IN PIPES.

The actual discharge capacity of piping is not proportional to the crosssectional area alone, that is, to the square of the diameter. Although the periphery is directly proportional to the diameter, the interior surface resistance is much greater in a small pipe than in a large one, because, as

the pipe becomes smaller, the ratio of perimeter to area increases, To pass a given volume of compressed air, a 1" pipe of given length requires over three times as much head as a 2" pipe of the same length. quires over three times as much head as a 2" pipe of the same length. The character of the pipe, also, and the condition of its inner surface, have much to do with the friction developed by the flow of air. Besides imperfections in the surface of the metal, the irregularities incident on coupling together the lengths of pipe must increase friction. There are so few reliable data that the influences by which the values of some of the factors may be modified are not fully understood; and, owing to these uncertain conditions, the results obtained from formulas are only approximately correct.

Among the formulas in common use, perhaps the most satisfactory is that of D'Arcy. As adopted for compressed-air transmission, it takes the form:

$$D=c\sqrt{\frac{d^5(p_1-p_2)}{w_1l}},$$

in which D =volume of compressed air in cubic feet per minute discharged at final pressure;

c = coefficient varying with diameter of pipe, as determined by

experiment;

d = diameter of pipe in inches (the actual diameters of 1½" and 1½" pipe are 1.38" and 1.61", respectively; the nominal diameters of all other sizes may be taken for calculations. lations);

l = length of pipe in feet;

 p_1 = initial gauge pressure in pounds per square inch:

 \dot{p}_2 = final gauge pressure in pounds per square inch; \dot{w}_1 = density of air, or its weight in pounds per cubic foot, at

initial pressure p_1 .

• the coefficients c for sizes of piping up to 12" are:

THE VALUES OF	me coemic		maco or bibini	5 up 10 14	arc.
1"	45.3	5"	59.0	9′′	61.0
2"	52.6	6''	59.8	10''	61,2
3''	56.5	7′′	60.3	11"	61.8
4"	58.0	8′′	60.7	12"	62.0

Some apparent discrepancies exist for sizes larger than 9", but they cause no very material differences in the results.

Another formula, published by Mr. Frank Richards, is as follows: V^2L

$$H = \frac{V^2 L}{V^2 L},$$

10,000 D5 a in which H = head or difference of pressure required to overcome friction and maintain the flow of air;

V = volume of compressed air delivered in cubic feet per minute:

L = length of pipe in feet;

D = diameter of pipe in inches;

a =coefficient, depending on the size of pipe.

Values of a for nominal diameters of wrought-iron pipe:

	044	B 00	011 1 101
1′′	3′′	.730	8" 1.125
11	34′′	.787	10'' 1.200
11/'	4''	.840	12" 1.260
2''	5′′	.934	
01// 650	211	1 000	

The values of a for $1\frac{1}{4}$ " and $1\frac{1}{4}$ " pipe are not consistent with those for other sizes, for the reason stated above. In using this formula with its constants, the calculated losses of pressure are found to be smaller, and, conversely, the volumes of air discharged are larger, under the same condi-

tions, than those obtained from D'Arcy's formula.

It must be remembered that, within certain limits, the loss of head or pressure increases with the square of the velocity. To obtain the best results, it is found in practice that the velocity of flow in the main air pipes should not exceed 20 or 25 ft. per second. When the initial velocity much exceeds 50 ft. per second, the percentage loss becomes very large; and, conversely, by using piping large enough to keep down the velocity, the friction loss may be almost eliminated. For example, at the Hoosac tunnel, in transmitmay be almost eliminated. For example, at the Hoosac tunnel, in transmitting 875 cu. ft. of free air per minute, at an initial pressure of 60 lb., through an 8" pipe, 7,150 ft. long, the average loss including leakage was only 2 lb. A volume of 500 cu. ft. of free air per minute, at 75 lb., can be transmitted through 1,000 ft. of 3" pipe with a loss of 4.1 lb., while if a 5" pipe were used the loss would be reduced to .24 lb. The velocity of flow in the latter case is only 10 ft. per second.

In driving the jeddo mining tunnel, at Ebervale, Pa., two 3½" drills were used in each heading, with a 6" main, the maximum transmission distance being 10,800 ft. This pipe was so large in proportion to the volume of air required for the drills (230 cu. ft. free air per minute) that the loss was reduced to an extremely small quantity. A calculation shows a loss of .002 lb., and the gauges at each end of the main were found to record

practically the same pressure.

A due regard for economy in installation, however, must limit the use of very large piping, the cost of which should be considered in relation to the very large piping, the cost of which should be considered in relation to the cost of air compression in any given case. Diameters of from 4 to 6 in. for the mains are large enough for any ordinary mining practice. Up to a length of 3,00 ft., a 4" pipe will carry, per minute, 480 cu. ft. of free air compressed to 82 bb, with a loss of 2 lb, pressure. This volume of air will run four 3" drills. Under the same conditions, a 6" pipe, 5,000 ft. long, will carry 1,100 cu. ft. of free air per minute, or enough for 10 drills.

A mistake is often made in putting in branch pipes of too small a diameter. For a distance of, say, 100 ft., a 1½" pipe is small enough for a single drill, though a 1" pipe is frequently used. While it is, of course, admissible to increase the velocity of flow in short branches considerably beyond 20 ft, per second, extremes should be avoided. To run a 3" drill from a 1" pipe 100 ft. long, would require a velocity of flow of about 55 ft. per second, causing a loss of 10 lb. pressure.

causing a loss of 10 lb. pressure.

The plping for conveying compressed air may be of cast or wrought iron. If of wrought iron, as is customary, the lengths are connected either by sleeve couplings or by cast-iron flanges into which the ends of the plpe are screwed or expanded. Sleeve couplings are used for all except the large sizes. The smaller sizes, up to 1½ in., are butt-welded, while all from 1½ in. up are lap-welded, to insure the necessary strength. Wrought-iron spiral-seam riveted or spiral-weld steel tubing is sometimes used. It is made in lengths of 20 ft., or less. For convenience of transport in remote regions, rolled sheets in short lengths may be had. They are punched around the edges, ready for riveting, and are packed closely—4, 6, or more sheets in a bundle.

All joints in air mains and branches should be carefully made. Air leaks

All joints in air mains and branches should be carefully made. Air leaks are more expensive than steam leaks because of the losses already suffered in compressing the air. The pipe may be tested from time to time by allowing the air at full pressure to remain in the pipe long enough to observe the gauge. In case a leak is indicated, it should be traced and stopped immediately. In putting together screw joints, care should be taken that none of the white lead or other comprising materials it forced that the lead or other comprising materials it forced that the lead or other comprising materials it forced that the lead or other comprising materials it forced that the lead or other comprising materials it forced that the lead or other comprising materials it forced that the lead or other comprising materials it forced that the lead or other comprising materials it forced that the lead or other comprising materials it forced that the lead or other comprising materials it forced that the lead or other comprising materials in the lead of the the white lead or other cementing material is forced into the pipe. This would cause obstruction and increase the friction loss. Also, each length as put in place should be cleaned thoroughly of all foreign substances that may have lodged inside. To render the piping readily accessible for inspection

and stoppage of leaks, it should, if buried, be carried in boxes sunk just below the surface of the ground; or, if underground, it should be supported upon brackets along the sides of the mine workings. Low points in pipe lines, which would form "pockets" for the accumulation of entrained water, should be avoided, as they obstruct the passage of the air. pipe lines, where a uniform grade is impracticable, provision may be made near the end for blowing out the water at intervals, when the air is to be used for pumps, hoists, or other stationary engines.

For long lengths of piping, expansion joints are required, particularly when on the surface. They are not often necessary underground, as the temperature is usually nearly constant, except in shafts, or where there may

be considerable variations of temperature between summer and winter. LOSSES IN THE TRANSMISSION OF COMPRESSED AIR.

By E. Hill, Norwalk Iron Works Co.

The increasing use that is being made of compressed-air engines for mine and underground work stimulates the inquiry regarding their efficiency.

d underground work sumulates an air com-The situation is apparently very simple. An engine drives an air com-the situation is apparently very simple. An engine drives an air com-The air under pressure is led pressor, which forces air into a reservoir. through pipes to the air engine, and is there used after the manner of steam.

The resulting power is frequently a small percentage of the power expended. In a large number of cases the losses are due to poor designing, and are not chargeable as faults of the system or even to poor workmanship.

The losses are chargeable, first, to friction of the compressor. This will amount ordinarily to 15% or 20%, and can be helped by good workmanship, but cannot probably be reduced below 10%. Second, we have the loss occasioned by pumping the air of the engine room, rather than air drawn from a cooler place. This loss varies with the season, and amounts to from 3% to 10%. This can all be saved. The third loss or series of losses arises in the compressing cylinder. Insufficient supply, difficult discharge, defective cooling arrangements, poor lubrication, and a host of other causes, perplex the designer and rob the owner of power. The fourth loss is found in the pipe. This has heretofore received by no means the consideration that the subject demands. The loss varies with every different situation, and is subject to somewhat complex influences. The fifth loss is chargeable to fall of temperature in the cylinder of the air engine. Losses arising from leaks are often serious, but the remedy is too evident to require demonstration. leak can be too small to require immediate attention. An attendant who is careless about packings and hose couplings will permit losses for which no amount of engineering skill can compensate.

We can only realize 100% efficiency in the air engine, leaving friction out of our consideration, when the expansion of the air and the changes of its temperature in the expanding or air-engine cylinder are precisely the reverse of the changes that have taken place during the compression of the air in the compressing cylinder. But these conditions can never be realized. The air during compression becomes heated, and during expansion it becomes cold. If the air immediately after compression, before the loss of any heat, was used in an air engine and there perfectly expanded back to atmospheric pressure, it would, on being exhausted, have the same temperature it had before compression, and its efficiency would be 100%.

But the loss of heat after compression and before use cannot be prevented, as the air is exposed to such very large radiating surfaces in the reservoir and pipes, on its passage to the air engine. The heat, which reservoir and pipes, of the passage to the sessages in this way, did, while in the compression; and since it is sure to escape, at the resistance of the air to compression, and since it is sure to escape, at some time, either in reservoir or pipes, it is evidently the best plan to remove it as fast as possible from the cylinder, and thus remove one element Hence, we find compressors are almost universally provided with cooling attachments more or less perfect in their action, the aim being to secure isothermal compression, or compression having equal temperature Where the temperature rises, without check, during comthroughout. pression, the term adiabatic compression is employed.

If air compressed isothermally is used with perfect expansion and the

fall of temperature during expansion be prevented, then we will have 100% efficiency. But air will grow cold on being expanded in an engine, and hence we conclude that warming attachments have the same economic place on an air engine that cooling attachments have on an air compressor. In fact, we find attachments of this kind more particularly in large and permanently located engines, but, for practical reasons, their use on most of the engines for mine work is dispensed with, and the engines expand the

air adiabatically, or without receiving heat.

The practical engineer, therefore, has to deal with nearly isothermal compression, and nearly adiabatic expansion, and must also consider that the air in reservoirs and pipes becomes of the same temperature as surrounding objects. Consideration must also be had for the friction of the compressor and the air engine. For the pressure of 60 lb., which is that most commonly used, the decrease in resistance to compression secured by the cooling attachments, is almost exactly equaled by the friction of the compressor. Hence it is safe, in calculating the efficiency of the air engine, to consider the compressor as being without cooling attachments, and also as working without friction. The results of such calculations will be too high efficiencies for light pressures, which are little used; about correct for medium pressures, which are commonly employed; and too low for higher pressures, and will thus have the advantage of not being overestimated. This result is occasioned by the fact that, owing to the slight heat in compressing low pressures of air, the saving of power by the cooling attachments is not equal to the friction of the machine, but at high pressures, on account of the great heat, the cooling attachments are of great value and save very much more power than friction consumes.

In the expanding engines, the expansion never falls as low as the adiabatic law would indicate, owing to a number of reasons, but we will consider the expansion as being adiabatic, as an error in calculations caused thereby will be on the "safe side" and the actual power will exceed the calculated power. We therefore consider the compressor and engine as the calculated power. following the adiabatic law of compression and expansion, and as working

without friction.

With this view of the case, the efficiency of an air engine, working with perfect expansion, stated in percentages of the power required to operate the compressor, can be placed as below for the various pressures above the

atmosphere.

```
Pressure above the atmosphere, 2.9 lb.
                                               94.85% efficiency.
Pressure above the atmosphere, 14.7 lb.
                                               81.79≸ efficiency.
Pressure above the atmosphere, 29.4 lb.
                                               72.72≸ efficiency.
Pressure above the atmosphere, 44.1 lb.
                                               66.90% efficiency.
                                               62.70 € efficiency.
Pressure above the atmosphere, 58.8 lb.
                                               59.48≸ efficiency.
Pressure above the atmosphere, 73.5 lb.
                                              56.88% efficiency.
Pressure above the atmosphere, 88.2 lb.
```

We observe that the efficiencies for the lower pressures are very much greater than for the high pressures, and the conclusion is almost irresistible that to secure economical results we must design our air engines to run with light pressures. And, in fact, the consideration of tables similar to the above, heretofore published by writers on this subject, has led many

The pipe has been entirely neglected. We notice that a pressure of 2.9 lb. is credited with an efficiency of 94.85%. It is clear that if the air were conveyed through a pipe, and the length of the pipe and the velocity of flow were such that 2.9 lb. pressure was lost in friction, then its efficiency, instead of being 94.85%, would be absolutely zero. It is, therefore, the power that we can get from the air, after it has passed the pipe and lost a part of its pressure by friction, which we must consider when we state the efficiency of our entire apparatus.

Our table of efficiencies with a loss of 2.9 lb. in the pipe, now gives us dif-

ferent values for the efficiencies at the various pressures.

```
Pressure above the atmosphere, 2.9 lb.
Pressure above the atmosphere, 14.7 lb.
Pressure above the atmosphere, 29.4 lb.
                                                        00.00% efficiency.
                                                       70.44% efficiency.
                                                        68.81% efficiency.
Pressure above the atmosphere, 44.1 lb.
                                                        64.87% efficiency.
Pressure above the atmosphere, 58.8 lb.
                                                        61.48% efficiency.
Pressure above the atmosphere, 73.5 lb.
                                                        58.62% efficiency.
Pressure above the atmosphere, 88.2 lb.
                                                        56.23% efficiency.
```

It will be noticed that the light pressures have lost most by the pipe friction, 2.9 lb. having lost 100% 14.7 lb. 114, and 88.2 lb. only a trifle over 1 of 14. We see that now 14.7 lb. is apparently the economical pressure to use. But a further careful analysis of the subject shows, that when the loss in the pipe is 2.9 lb., then 20.5 lb. is the most economical pressure to use, and that the efficiency is 71%. But 2.9 lb. is a very small loss between compressor and air engine, and cases are extremely exceptional where the friction of valves, pipes, elbows, ports, etc. does not far exceed this. Yet, with these conditions, which are very difficult to fill, we see that 20.5 lb. is the lightest pressure that should probably ever be used for conveying power, and that 71% is an efficiency scarcely to be obtained.

Continuing our investigation and taking examples where the pipe friction amounts to 5.8 lb., we find the following efficiencies to correspond to the

stated pressure:

```
Pressure above the atmosphere, 14.7 lb.
                                                             57.14% efficiency.
64.49% efficiency.
Pressure above the atmosphere, 29.4 lb.
                                                             62.71% efficiency.
Pressure above the atmosphere, 44.1 lb.
                                                             60.12% efficiency.
57.73% efficiency.
55.59% efficiency.
Pressure above the atmosphere, 58.8 lb. Pressure above the atmosphere, 73.5 lb.
Pressure above the atmosphere, 88.2 lb.
```

We again notice that as friction increases, or in other words, when we begin to use more air and make greater demands on the carrying capacity of the pipe, then we must increase pressure very considerably to attain the most economical results. If the demands are such as to increase the friction and loss in pipe to 14.7 lb., the air of 14.7 lb. pressure at the compressor is entirely useless at the air engine.

The table will stand thus:

```
Pressure above the atmosphere, 14.7 lb. Pressure above the atmosphere, 29.4 lb.
                                                               00.00% efficiency.
                                                               48.53% efficiency.
55.13% efficiency.
Pressure above the atmosphere, 44.1 lb.
Pressure above the atmosphere, 58.8 lb. Pressure above the atmosphere, 73.5 lb.
                                                               55.64% efficiency.
                                                               54.74% efficiency.
                                                               53.44% efficiency.
Pressure above the atmosphere, 88.2 lb.
```

It is to be noticed that 88.2 lb. pressure has lost only about 34% of its efficiency by reason of as high a friction as 14.7 lb., while the efficiency of

the lower pressures has been greatly affected.

As the friction increases we see that the most efficient, and, consequently, most economical, pressure increases. In fact, for any given friction in a pipe, the pressure at the compressor must not be carried below a certain limit. The following table gives the lowest pressures that should be used at The following table gives the lowest pressures that should be used at the compressor, with varying amounts of friction in the pipe:

```
2.9 lb. friction.
                      20.5 lb. at compressor.
                                                    70.92% efficiency.
                      29.4 lb. at compressor.
                                                    64.49% efficiency.
60.64% efficiency.
 5.8 lb. friction.
 8.8 lb. friction.
                      38.2 lb. at compressor.
11.7 lb. friction.
                      47.0 lb. at compressor.
                                                    57.87% efficiency.
14.7 lb. friction.
                      52.8 lb. at compressor.
                                                    55.73% efficiency.
17.6 lb. friction.
                      61.7 lb. at compressor.
                                                    53.98% efficiency.
                      70.5 lb. at compressor.
20.5 lb. friction.
                                                    52.52% efficiency.
23.5 lb. friction.
                      76.4 lb. at compressor.
                                                    51.26% efficiency.
26.4 lb. friction.
                      82.3 lb. at compressor.
                                                    50.17% efficiency.
                      88.2 lb. at compressor.
                                                    49.19% efficiency.
29.4 lb. friction.
```

So long as the friction of the pipe equals the amounts given above, an efficiency greater than the corresponding sums stated in the table cannot be expected. If we should have a case that corresponded to any of these state. If we should have a case that corresponded to any of these cited

in the table, we could only increase efficiency by reducing the friction.

An increase in the size of pipe will reduce friction by reason of the lower velocity of flow required for the same amount of air. But many situations velocity of flow required for the same amount of air. But many situations will not admit of large pipes being employed, owing to considerations of

economy outside of the question of fuel or prime motor capacity.

An increase of pressure will decrease the bulk of air passing the pipe, and in that proportion will decrease its velocity. This will decrease the loss by friction, and, as far as that goes, we have a gain. But we subject ourselves to a new loss, and that is the diminishing efficiencies of increasing pressures. Yet as each cubic foot of air is at a higher pressure, and, therefore, carries more power, we will not need as many cubic feet as before for the same It is obvious that with so many sources of gain or loss the question of selecting the proper pressure is not to be decided hastily.

As an illustration of the combined effect of these different elements, we

will suppose a very common case.

Compressor 102 revolutions, pressure 52.8 lb., loss in pipe 14.7 lb., machine in mine running at 38.2 lb., efficiency 55.73%.

So long as the friction of the pipe amounts to 14.7 lb., we have seen that 52.8 lb. is the best pressure and 55.73% the greatest efficiency. reduce the friction by reducing the bulk of air passing through the pipe. We reduce the cylinder of the air engine so that it requires 47 lb. pressure to do the same work as before. We find now that the friction of pipe drops to 11.7 lb. The pressure on the compressor rises to 58.8 lb., its number of revolutions falls to 100, and the resulting efficiency is 57.22%.

Another change of pressure on compressor to 64.7 lb. would decrease its revolutions to 33, friction to 8.8 lb., and efficiency would rise to 57.94%. Still again increasing the pressure to 73.5 lb., we have only 84 revolutions of compressor, 5.8 lb. loss in pipe, and efficiency of 57.73%. In this last case the efficiency begins to fall off a little, and higher pressures would now show less efficiency; but, in comparison with the first example, we find we are doing the same work in the mine with a trifle less power and with a decrease of nearly 20% in the speed of the compressor.

Other common examples can be shown where an increase of processor.

Other common examples can be shown where an increase of pressure would result in wonderful increase in efficiency and economy. There are many cases where light pressures and high velocity in the pipe will convey a given power with greater economy than higher air pressures and lower speed of flow through the pipe. But these cases arise mostly when the higher air pressures become very much greater than are at present in com-

mon use.

Therefore, in estimating the efficiency of the complete outfit, we find that the pipe and the pressure are very important elements, and must be determined with care and skill to secure the most satisfactory results. volume and power of air vary with its pressure, the size and consequent cost of compressor for a certain work would also be affected by the pressure. To plan an outfit for a mine, due regard must be had to cost of fuel or prime motor power, and also to cost of compressor, pipes, and machinery, as the saving in one is often secured by a sacrifice in the other.

Next to determining the size of pipe, the skilful engineer has need of further care in the proper position of reservoirs, branches, drains, and other attachments, as only by the exercise of good judgment in this can satis-

factory working be secured.

The fact that, on account of the diminished density of the atmosphere at high altitudes, air compressors do not give the same results as at sea level, should also be taken into consideration when a compressor is to be installed

in a mountainous region.

Friction of Air in Pipes.—Air in its passage through pipes is subject to friction in the same manner as water or any other fluid. The pressure at the compressor must be greater than at the point of consumption in order to overcome this resistance. The power that is needed to produce the extra pressure representing the friction of the pipe is lost, as there can be no useful return for it. The friction is affected by very many circumstances, but chiefly to be noted is the fact that it increases in direct proportion to the length of the pipe and also as the square of the velocity of the flow of air. The pressure of the air does not affect it.

The losses by friction may be quite serious if the piping system is poorly designed, and, on the other hand, extravagant expenditure in pipe may result from a timid overrating of the evils of friction. A thorough knowledge of the laws governing the whole matter, as well as a ripe experience, is

necessary to secure true economy and mechanical success.

The loss of power in pipe friction is not always the most serious result. When a number of machines are in use in a mine, and the pipes are so small as to cause a considerable loss of pressure by friction, then there will be sudden and violent fluctuations in pressure whenever a machine is started or stopped. Breakages will be of common occurrence, as the changes are too quick to be entirely guarded against by the attendant. Perfectly even pressure at the compressor is no safeguard against this class of accidents. trouble arises in the pipe, and the remedy must be applied there. A system of reservoirs and governing valves will regulate these matters and allow successful work to be done with pipes, which would otherwise be entirely inadmissible.

The ordinary formulas for calculating the volume of air transmitted through a pipe do not take into account the increase of volume due to reduction of pressure, i. e., loss of head. To transmit a given volume of air at a uniform velocity and loss of pressure, it would be necessary to construct the pipe with a gradually increasing area. This, of course, is impracticable, and in pipe of uniform section both volume and velocity must increase as the pressure is reduced by friction. The loss of head in properly propor-tioned pipes is so small, however, that in practice the increase in volume is usually neglected.

Loss of Pressure in Pounds per Square Inch, by Flow of Air in Pipes. Calculated for pipes 1,000 ft. long: for other lengths, the loss varies directly as the length.

Velocity of Air at Entrance to Pipe.			1" Pipe.		2" Pipe.			2	¹″ Pip	e.
Meters per Second.	Feet per Second.	Loss of Pressure. Pounds.	Cubic Feet of Free Air Passed per Minute When Compressed to 60 Lb. Above the Atmosphere.	Cubic Feet of Free Air Passed per Minute When Compressed to 80 Lb. Above the Atmosphere.	Loss of Pressure. Pounds.	Cubic Feet of Free Air Compressed to 60 Lb.	Cubic Feet of Free Air Compressed to 80 Lb.	Loss of Pressure. Pounds.	Cubic Feet of Free Air Compressed to 60 Lb.	Cubic Feet of Free Air Compressed to 80 Lb.
1 2 3 4 5 6 8 10	3:28 6.56 9.84 13.12 16.40 19.68 26.24 32.80	.1435 .6405 1.4545 2.5620 3.9345 5.4225 10.2480 15.7380	6 12 18 24 29 35 47 59	7 15 22 29 37 44 59 74	.0794 .3050 .7216 1.2566 1.9642 2.7120 5.0264 7.8568	23 46 69 93 116 139 185 232	29 59 88 117 146 175 234 294	.0574 .2562 .5818 1.0248 1.5738 2.1690 4.0992 6.2952	32 65 97 130 163 195 260 326	41 82 124 165 207 247 330 413
			3" Pipe		4	" Pipe		5	" Pipe	.0761
1 2 3 4 5 6 8 10	3.28 6.56 9.84 13.12 16.40 19.68 26.24 32.80	.0463 .2092 .4880 .8381 1.3176 1.8080 3.3525 5.2704	48 96 144 193 241 289 386 480	60 121 182 243 304 364 486 607	.0347 .1525 .3608 .6283 .9821 1.3560 2.5132 3.9284	86 172 258 343 429 515 687 859	109 217 326 436 544 653 871 1,088	.0287 .1281 .2909 .5124 .7869 1.0845 2.0496 3.1476	134 268 402 537 671 805 1,073 1,342	169 239 509 678 844 1,017 1,357 1,696
			6" Pipe		8	" Pipe		10	" Pipe	
1 2 3 4 5 6 8 10	3.28 6.56 9.84 13.12 16.40 19.68 26.24 32.80	.0232 .1046 .2440 .4190 .6588 .9040 1.6762 2.6352	193 386 579 772 965 1,158 1,544 1,931	244 488 633 977 1,221 1,466 1,954 2,443	.0173 .0762 .1805 .3141 .4910 .6780 1.2556 1.9642	343 687 1,030 1,373 1,717 2,060 2,747 3,434	434 864 1,303 1,736 2,171 2,605 3,473 4,342	.0143 .0640 .1455 .2562 .3934 .5423 1.0248 1.5738	537 1,073 1,610 2,146 2,683 3,220 4,293 5,367	680 1,359 2,039 2,719 3,399 4,079 5,438 6,798

The resistance is not varied by the pressure, only so far as changes in pressure vary the velocity. It increases about as the square of the velocity.

and directly as the length.

Elbows, short turns, and leaks in pipes all tend to reduce the pressure in addition to the losses given in the table.

TABLE OF LOSS BY FRICTION IN ELBOWS.

An elbow with a radius of one-half the diameter of the pipe is as short

Equivalent length of straight pipe,	7.85 diams.
Equivalent length of straight pipe,	8.24 diams.
Equivalent length of straight pipe,	9.03 diams.
Equivalent length of straight pipe,	10.36 diams.
Equivalent length of straight pipe.	12.72 diams.
Equivalent length of straight pipe.	17.51 diams.
Equivalent length of straight pipe.	35.09 diams.
Equivalent length of straight pipe,	121.20 diams.
	Equivalent length of straight pipe, Equivalent length of straight pipe, Equivalent length of straight pipe, Equivalent length of straight pipe,

ELECTRICITY.

PRACTICAL UNITS.

In electrical work it is necessary to have units in terms of which to express the different quantities entering into calculations. The four most important of these are used to express strength of current; electrical pressure,

important of these are used to express strength of current; electrical pressure, or electromotive force; resistance; power.

The strength of current flowing in a wire may be measured in several ways. If a compass needle be held under or over a wire, it will be deflected and will tend to stand at right angles to the wire. The stronger the current, the greater the deflection of the needle. If the wire carrying the current be cut and the ends dipped into a solution of silver nitrate, silver will be deposited on the end of the wire toward which the current is flowing, and the amount of silver deposited in a given time will be directly proportional to the average strength of current flowing during that time. When the current flowing in a wire is spoken of, the strength of the current is meant.

Unit Strength of Current.—The unit used to express the strength of a current is called the ampers. If a current of 1 ampere be sent through a bath of silver nitrate, 001118 gram of silver will be deposited per second. The expression of the flow of current through a wire as so many amperes is analogous to the expression of the flow of water through a pipe as so many

analogous to the expression of the flow of water through a pipe as so many

gallons per second.

Electromotive Force.—In order that a current may flow through a wire, there must be an electrical pressure of some kind to cause the flow. In hydraulics, there must always be a head or pressure before water can be made to flow through a pipe. It is also evident that there may be a pressure or head without there being any flow of water, because the opening in the pipe might be closed; the pressure would, however, exist, and, as soon as the valve closing the pipe was opened, the current would flow. same way, an electrical pressure or electromotive force (usually written E. M. F.) may exist in a circuit, but no current can flow until the circuit is closed or until the wire is connected so that there will be a path for the current.

Unit Electromotive Force (E. M. F.).—The practical unit of electromotive force is the volt. It is the unit of electrical pressure, and fulfils somewhat the same purpose as "pounds per square inch" in hydraulic and steam engineering. The E. M. F. furnished by an ordinary cell of a battery usually varies from .7 to 2 volts. A Daniell cell gives an E. M. F. of 1.072 volts. A pressure of 500 volts is generally used for street-railway work, and, for incandescent lighting, 110 volts is common.

Resistance. -All conductors offer more or less resistance to the flow of a current of electricity, just as water encounters friction in passing through a pipe. The amount of this resistance depends on the length of the wire, the diameter of the wire, and the material of which the wire is composed. The

resistance of all metals also increases with the temperature

Unit of Resistance.—The practical unit of resistance is the ohm. A conductor has a resistance of 1 ohm when the pressure required to set up 1 ampere through it is 1 volt. In other words, the drop, or fall, in pressure through a resistance of 1 ohm, when a current of 1 ampere is flowing, is 1 volt. 1,000 ft. of copper wire 1 in. in diameter has a resistance of nearly 1 ohm at ordinary temperatures.

Ohm's Law .- The law governing the flow of current in an electric circuit Ohm's Lew.—The law governing the flow of current in an electric circuit was first stated by Dr. G. S. Ohm, and is known as Ohm's law. This law has since stood the test of exhaustive experiment, and has been found correct. Ohm's law may be briefly stated as follows: The strength of the current in any circuit is directly proportional to the electromotive force in the circuit, and inversely proportional to the resistance of the circuit.

This means that if the resistance of a circuit were fixed, and the E. M. F. varied, the current would be doubled if the E. M. F. were doubled. Also, if the E. M. F. were fixed, and the resistance doubled, the current would be believed.

halved. Let

E = electromotive force in volts; R = resistance in ohms; C = current in amperes.

Then,

$$C = \frac{E}{R}$$
, or $R = \frac{E}{C}$ or $E = CR$.

The last two forms are useful in many cases where the usual form $C = \frac{E}{D}$ is not directly applicable.

EXAMPLE.—A dynamo D which generates 110 volts, is connected to a coil of wire C, Fig. 1, which has a resistance of 20 ohms; what current will flow, supposing the resistance of the rest of the circuit to be negligible?

We have E=110 volts; R=20 ohms; hence, $C=\frac{110}{20}$ = 5.5 amperes.

A problem might also be given as follows: The resistance of the coil C is 6 ohms; what E. M. F. must the dynamo generate in order to set up a current of 15 amperes through it? The third form of the law given above is more convenient in this case.

E-110 Volts CO Fig. 1

$$E = CR$$
; $E = 15 \times 6 = 90$ volts.
In case the current and E. M. F. are known, the resistance of the circuit may be calculated

by using the second form of the law given above. For example, if the current in the above case were 8 amperes and the E. M. F. of the dynamo 110 volts, the resistance of the circuit must be

$$R = \frac{E}{C}$$
; $R = \frac{110}{9} = 13.75$ ohms.

Electrical Power.—The electrical power expended in any circuit is found by multiplying the current flowing in the circuit by the pressure required to force the current through the circuit. In other words, W = E C; where W is the power expended, E is the E. M. F., and C is the current. When Eis expressed in volts and C in amperes, then W is expressed in watts. The what is the unit of electrical power, and is equal to the power developed when 1 ampere flows under a pressure of 1 volt. The watt is equal to 74π horsepower. We have, then, the following general relations:

Let

E =electromotive force in volts;

C =current in amperes;

R = resistance in ohms; W = power in watts; H. P. = horsepower.

Then, W=EC, but E=CR; hence, $W=C^2R$. That is, the power in watts expended in any conductor of which the resistance is R, and through which a current C is flowing, is equal to the product of the squares of the current and the resistance. The energy used in forcing a current through the wire reappears in the form of heat; hence, we may say that the heating effect of a current flowing in a conductor is proportional to the square of the current. From the preceding, we also have

H. P. =
$$\frac{E C}{746} = \frac{W}{746}$$
.

This relation is very useful for calculating power in terms of electrical units. The watt is too small a unit for convenient use in many cases, so that the kilowatt, or 1,000 watts, is frequently used. This is sometimes abbreviated to K.W.

The Unit of Work is the Watt-Hour.—This is the total work done when 1 watt is expended for 1 hour. For example, if a current of 1 ampere were made flow for 1 hour through a resistance of 1 ohm, the total amount of work done would be 1 watt-hour. A kilowatt-hour is the total work done when 1 kilowatt is expended for 1 hour. It is about equivalent to 14 horsepower for 1 hour.

EXAMPLE.—In the case shown in Fig. 1, calculate the number of watts

expended in the coil C.

The pressure is 110 volts and the current is 5.5 amperes; hence, $W = E \times C = 110 \times 5.5 = 605$ watts.

The same result might have been obtained from the formula. $W = C^2 R = (5.5)^2 \times 20 = 605$ watts.

The horsepower expended would be

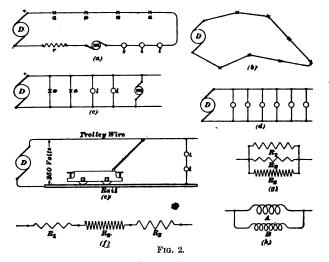
$$\frac{W}{746} = \frac{605}{746} = .811.$$

EXAMPLE.—The current supplied to an electric motor is 120 amperes and the pressure between the mains is 220 volts. What is the power supplied in kilowatts? What is the horsepower supplied? $W = E \times C = 220 \times 120 = 26,400$ watts = 26.4 K.W.

H. P.
$$=\frac{26,400}{746}=35.39$$
.

CIRCUITS.

The path through which a current flows is generally spoken of as an electric circuit. This path may be made up of a number of different parts. For example, the line wires may constitute part of the circuit, and the remainder may be composed of lamps, motors, resistances, etc. In practice, the two



kinds of circuits most commonly met with are (1) those in which the dif-ferent parts of the circuit are connected in series; (2) those in which the different parts of the circuit are connected in multiple or parallel.

1. Series Circuits. - In this kind of circuit, all the component parts are connected in tandem, so that the current flowing through one part also flows

through the other parts. Fig. 2 (a) represents such a circuit made up of a different number of parts. The current leaves the dynamo D at the + side and flows through the arc lamps a a a a, thence through the incandescent lamps lll, thence through the motor m and resistance r, back to the dynamo, thus making a complete circuit. All these different parts are here connected in series, so that the current flowing through each of the parts must be the same unless leakage takes place across from one side of the circuit to the other, and this would be impossible if the lines were properly insulated. The pressure furnished by the dynamo must evidently be the sum of the pressures required to force the current through the different parts. The most common use of this system is in connection with arc lamps. These lamps are usually connected in series, as shown in Fig. 2 (b). The objections to this system of distribution for general work are that the breaking of the circuit at any point cuts off the current from all parts of the circuit; also, the pressure generated by the dynamo has to be very high if many pieces of apparatus are connected in series. In such a system, the dynamo is provided with an automatic regulator that increases or decreases the *voltage* of the machine, so that the *current* in the circuit is kept constant, no matter how many lamps or other devices are in operation. For this reason, such

circuits are often spoken of as constant-current circuits.

2. Perellel Circuits.—In this type of circuit, the different pieces of apparatus of the circuits o ratus are connected side by side, or in parallel, across the main wires from the dynamo, as shown in Fig. 2 (c). In this case, the dynamo D supplies current through the mains to the arc lamps a, incandescent lamps l, and motor m. This system is more widely used, and it will be seen at once from motor m. This system is more winery used, and a win to see a fapparatus the figure that the breaking of the circuit through any one piece of apparatus will not prevent the current from flowing through the other parts. Incandessent lamps are connected in this way almost exclusively. The lamps are connected directly across the mains, as shown in Fig. 2 (d). Street cars and mining locomotives are operated in the same way, the trolley wire constituting one main and the track the other, as shown in Fig. 2 (e). By adopting this system, any car can move independently of the others, and the current may be turned off and on at will. In all these systems of parallel distribu-tion, the pressure generated by the dynamo is maintained constant, no matter what current the dynamo may be delivering. For example, in the lamp system, Fig. 2 (d), the dynamo would maintain a constant E. M. F. of 110 volts. Each lamp has a fixed resistance, and will take a certain current

 $\left(\frac{110}{R}\right)$ amperes when connected across the mains. As the lamps are turned

on, the current delivered by the dynamo increases, the pressure remaining constant. In street-railway work, the pressure between trolley and track is kept in the neighborhood of 500 volts, the current varying with the number of cars in operation. In mine-haulage plants, the pressure is usually 250 or 500 volts, the former being generally preferred as being less dangerous Lamps may also be connected in series multiple, as shown in Fig. 2 (e). Here the two 125-volt lamps ll are connected in series across the 250-volt circuit. Such an arrangement is frequently used in mines when lamps are operated from the haulage circuit.

Such circuits as those just described are called constant-potential or constant-pressure circuits, to distinguish them from the constant-current circuit

mentioned previously.

RESISTANCES IN SERIES AND MULTIPLE.

Resistances in Lines.—If two or more resistances are connected in series. Fig. 2 (f), their total combined resistance is equal to the sum of their separate resistances. If R equal total combined resistance, and R_1 , R_2 , R_3 are the separate resistances connected in series, then, $R = R_1 + R_2 + R_3$.

EXAMPLE.—If the separate resistances were $R_1 = 10$ ohms, $R_2 = 1$ ohm,

and $R_3 = 30$ ohms, then these three combined would be equivalent to a

single resistance of 10+1+30=41 ohms.

Resistances in Parallel.—If a number of resistances are connected in parallel, the reciprocal of their total combined resistance is equal to the sum of the reciprocals of the separate resistances. In Fig. 2 (g), three resistances are shown connected in parallel. It is evident that the total resistance of such a combination must be lower than that of the lowest resistance entering into the combination. If the resistances in this case were all equal.

the resistance of the three combined would be one-third the resistance of **One of them,** because a current passing through the three combined could split up between three equal paths, instead of having only one path to pass through. If R represents the combined resistance, and R_1 , R_2 , and R_3 the separate resistances, the following relation is true:

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_8},$$

$$R = \frac{R_1}{R_2 R_3 + R_1 R_3 + R_1 R_2}.$$

from which

If the three resistances were all equal, we would have $\frac{1}{R} = \frac{3}{R_1}$, or $R = \frac{R_1}{3}$.

EXAMPLE.—Three resistances of 3, 10, and 5 ohms are connected in parallel. What is their combined resistance? We have

$$\frac{1}{R} = \frac{1}{3} + \frac{1}{10} + \frac{1}{5}$$
, or $R = \frac{150}{50 + 15 + 30} = \frac{150}{95} = 1.58$ ohms.

Shunt.—When one circuit B, Fig. 2 (h), is connected across another A, so as to form, as it were, a by-pass, or side track, for the current, such a circuit is called a shunt, or it is said to be in shunt with the other circuit.

ELECTRIC WIRING (CONDUCTORS).

Materials.—Practically all conductors used in electric lighting or power work are of copper, this metal being used on account of its low resistance. Iron wire is used to some extent for conductors in telegraph lines, and steel is largely used as the return conductor in electric-railway or haulage plants where the current is led back to the power station through the rails. The resistance of iron or steel varies from six to seven times that of copper, depending on the quality of the metal. Aluminum is coming into use as a material for conductors, and in future may play an important part in electric transmission. It is so much lighter than conpert that it is able to comprete transmission. It is so much lighter than copper that it is able to compete with it as a conductor, even though its cost per pound is higher and its conductivity only about 60% that of copper.

Forms of Conductors.-Most of the conductors used are in the form of copper wire of circular cross-section. Conductors of large cross-section are made up of a number of strands of smaller wire twisted together. For electrolytic plants, copper-refining plants, etc., copper bars of rectangular

electrolytic plants, copper-renning plants, etc., copper bars of rectangular cross-section are frequently used.

Wire Gauge.—The gauge most generally used in America to designate the different sizes of copper wire is the American, or Brown & Sharper (B. & S.). The sizes as given by this gauge range from No. 0000, the largest, .460 in diameter, to No. 40, the finest, .003 in diameter. Wire drawn to the sizes given by this gauge is always more readily obtained than sizes according to other gauges; hence, in selecting line wire for any purpose it is always desirable, if possible, to give the size required as wire of the B. & cauge. A wire can usually be selected from this cauge. a wire of the B. S. gauge. A wire can usually be selected from this gauge, which will be very nearly that required for any specified case.

Estimation of Cross-Section of Wires.—The diameter of round wires is

usually given in the tables in decimals of an inch, and the area of cross-section is given in terms of a unit called a circular mil. This is done simply for convenience in calculation, as it makes calculations of the cross-section much simpler than if the square inch were used as the unit area. A mi is $\tau_0 \tau_0$ of an inch, or .001 in. A circular mil is the area (in decimals of a square inch) of a circle, the diameter of which is $\tau_0 \tau_0$ in., or 1 mil. The

circular mil is therefore equal to $\frac{\pi}{4}$ (.001)² = .0000007854 sq. in.

If the diameter of the conductor were 1 in., its area would be .7854 sq. in., and the number of circular mils in its area would be $\frac{10000007854}{0000007854} = 1,000,000$;

but 1 in. = 1,000 mils, and $(1,000)^2 = 1,000,000$; hence the following is true: $CM = d^2$; or the area of cross-section of a wire in circular mils is equal to the square of its diameter expressed in mils.

EXAMPLE.—A wire has a diameter of .101 in. What is its area in circular mils?

.101 in. = 101 mils. Hence, $CM = (101)^2 = 10,201$.

The following table gives the dimensions, weight, and resistance of pure copper wire. The weights given are, of course, for bare wire. The first column gives the B. & S. gauge number, the second the diameter in mils. The diameter in inches would be the number as given in this column, divided by 1,000. The third column gives the area in circular mils, the numbers in this column being equal to the squares of those in the second column. The safe carrying capacity is also given.

PROPERTIES OF COPPER WIRE. AMERICAN, OR BROWN & SHARPE, GAUGE

Number. & S. Gauge.	Diameter in Mils	Circular 3. M. = d ² .		ight. unds.	Resistance per 1,000 Ft. International Ohms. 68º F.	(Am) Nations	Capacity peres). al Board erwriters
B. & Su	Diamet	Area in Mils. C.	Per 1,000 Ft.	Per Mıle.	Resist 1,0 Interi Ohms	Weath- er-Proof.	Rubber- Covered.
0000	460.0	211,600.0	640.50	3,381.4	.0489	312	210
000	409.6	167,805.0	508.00	2,682.2	.0617	262	177
00	364.8	133,079.4	402.80	2,126.8	.0778	220 185	150 127
0	324.9	105,534.5	319.50 253.30	1,686.9	.0981 .1237	156	107
- 5	289.3 257.6	83,694.2 66,373.0	200.90	1,337.2 1,060.6	.1560	100	107
2	229.4	52,634.0	159.30	841.1	.1967	131 110	90 76
A	204.3	41,742.0	126.40	667.4	.2480	92	65
5	181.9	33,102.0	100.20	529.1	.3128	77	54
6	162.0	26,250.5	79.46	419.5	.3944	65	46
7	144.3	20,816.0	63.02	332.7	.4973	"	20
1 2 3 4 5 6 7 8 9	128.5	16,509.0	49.98	263.9	.6271	46	33
9	114.4	13,094.0	39.63	209.2	.7908		
10	101.8	10,381.0	31.43	165.9	.9972	32	24
11	90.7	8,234.0	24.93	131.6	1.257		
12 13	80.8	6,529.9	19.77	104.4	1.586	23	17
13	71.9	5,178.4	15.68	82.8	1.999		
14 15	64.1	4,106.8	12.43	76.2	2.521	16	12
16 16	57.1 50.8	3,256.7 2,582.9	9.86 7.82	52.0 41.3	3.179 4.009	8	6
17	45.2	2,048.2	6.20	20.7	5.055	°	٥
18	40.3	1,624.3	4.92	32.7 25.9	6.374	5	3
19	35.9	1,288.1	3.90	20.6	8.038		ĺ
20	31.9	1,021.5	3.09	16.3	10.14		
21	28.5	810.1	2.45	12.9	12.78		
22 23	25.3 22.6	642.4	1.94	10.3	16.12		
23	22.6	509.4	1.54	8.1	20.32		
24	20.1 17.9	404.0	1.22	6.4	25.63		
25	17.9	320.4	.96	5.1	32.31		
26	15.9	254.1	.76	4.0	40.75		
26 27 28 29 30	14.2 12.6	201.5 159.7	.61 .48	3.2 2.5	51.38 64.79		
20	11.2	126.7	.38	2.0	81.7		}
30	10.0	100.5	.30	1.6	103.0		
31	8.93	79.70	.24	1.6 1.27	103.0 129.9 163.8	!	
32	7.95	63.21	.19	1.01	163.8		
31 32 33	7.08	50.13	.15	.801	206.6	1	
34	6.30	39.75	.12	.635	260.5		
35	5.61	31.52	.095	.504	328.4		
36	5.00	25.00	.075	.400	414.2		•
37	4.45	19.83	.060 .047	.317	522.2		
38	3.96	15.72	.047	.251	658.5		
39 40	3.53 3.14	12.47 9.89	.038	.199 .158	830.4 1,047.0	1	

The following table gives a comparison of the properties of aluminum and copper:

COMPARISON OF PROPERTIES OF ALUMINUM AND COPPER.

	Aluminum.	Copper.
Conductivity (for equal sizes)	.54 to .63	1
Weight (for equal sizes)	.33	ī
Weight (for equal length and resistance) Price (per pound) aluminum, 29 cents; cop-	.48	ī
per, 16 cents (bare wire)	1.81	1
line wire) Temperature coefficient per degree F	.868	1
Resistance of mil-foot (20° C.)	.002138	.002155
	18.73	10.5
Specific gravityBreaking strength (equal sizes)	2.5 to 2.68 1	8.89 to 8.93 1

In case a conductor larger than that given in the table is required, stranded cables are used. These are made in various sizes. The table below gives some of the more common sizes, with their allowable current capacity.

CARRYING CAPACITY OF CABLES.

Area.	Current.	Amperes.	Area.	Current. Amperes.		
Circular Mils.	Exposed.	Concealed.	Circular Mils.	Exposed.	Concealed.	
200,000 300,000 400,000 500,000 600,000 800,000 900,000 1,000,000 1,100,000	299 405 503 595 682 765 846 924 1,000 1,075	200 272 336 393 445 494 541 586 630 673	1,200,000 1,300,000 1,400,000 1,500,000 1,600,000 1,700,000 1,800,000 1,900,000 2,000,000	1,147 1,217 1,287 1,356 1,423 1,489 1,554 1,618 1,681	715 756 796 835 873 910 946 981 1,015	

Estimation of Resistance.—The resistance of any conductor is directly proportional to its length, and inversely proportional to its area of cross-section, or $R = K \frac{L}{A}$, where K is a constant. If L is expressed in feet and A is expressed in circular mils, then the constant K must be the resistance of a foot of the wire in question of 1 circular mil cross-section. The resistance of 1 mil-foot of copper wire at 75° F. is about 10.8 ohms. Hence, for copper wire, we have $R = \frac{10.8 L}{A}$; but $A = d^3$ when d is the diameter $\frac{10.8 L}{A}$ in $\frac{10.8 L}{A}$.

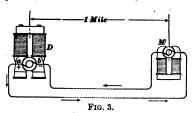
This formula is easily remembered, and is very convenient for estimating the resistance of any length of wire of given diameter when a wire table is not at hand, or when the diameter of the given wire does not correspond to anything eigen in the table.

in mils; hence, we also have R =

anything given in the table. EXAMPLE.—Find ther esistance of 1 mile of copper wire .20 in. in diameter. 1 mile = 5,280 ft. .20 in. = 200 mils. Area of cross-section = $(200)^2 = 40,000$ circular mils. Hence, $R = \frac{10.8 \times L}{10.8 \times L} = \frac{10.8 \times 5,280}{10.000} = 1.42$ ohms.

CALCULATION OF WIRES FOR ELECTRIC TRANSMISSION.

Direct-Current Circuits.—No matter how large a wire may be, some energy must always be expended in forcing a current through it, because no conductor can be entirely devoid of resistance. It is true that the loss may be made as small as we please by using a very large conductor, but, in practice. this would not pay, because the interest on the cost of the copper would more than counterbalance the gain in the efficiency of transmission. In starting out, then, to estimate the size of wire to transmit a given amount of power over a given distance, one of the first things to be decided is the amount of power that may be allowed for loss in the line, because it is evident that the greater the power lost, the higher may be the line resistance, and hence the smaller the wire. The pressure required to force a current C through a wire of resistance R is $C \times R$. This pressure is generally spoken Cthrough a wire of resistance K is $C \times K$. In this pressure is generally spoken of as the drop, for the reason that the pressure necessary to set up the current through the line is lost, and, consequently, the pressure falls off or drops from the dynamo to the receiving end of the line. In all cases, the pressure at the end of the line, or point where the power is delivered, is equal to the pressure at the dynamo less the drop in the line, and, conversely, the pressure that must be maintained by the dynamo in order to obtain a given pressure at the end will be equal to the pressure at the receiving end plus the drop in the line. To illustrate the above, take the case shown in Fig. 3, where a dynamo D supplies current to a motor M situated 1 mile distant where a dynamo D supplies current to a motor a student I must be supplied in order that the motor may operate properly, the pressure at its terminals must be kept constant at, say, 500 volts. It is evident, then, that the pressure between a and b (the dynamo terminals) must be more than 500 volts, by the drop or pressure necessary to force the current through the line. If the motor is taking very little current, i. e., if it is running on a very light load, the current will be small, and hence the drop in the line will be small. order, then, that the pressure at the motor may remain constant, or nearly so, the pressure at the dynamo must automatically increase as the load increases. The way in which this is done will be explained later: for the present, we are concerned only with the calculation of the line. The line



must evidently be designed with regard to the maximum current it has to carry. We will suppose, for the sake of illustration, that the motor takes 50 amperes at full load and that the line wire is of such size that it has a resistance of .2 ohm per mile. The current has to pass through 2 miles of wire (because it has to flow out through 1 mile), and hence encounters a resistance of .4 ohm. The drop in the

line will then be $4\times50=20$ volts, and in order to obtain a pressure of 500 volts at the motor, the pressure at the dynamo would have to be 520 volts. The loss of power in the line would be current \times drop = 50 \times 20 = 1,000 watts, or about 14 horsepower. The drop in an electrical transmission line is analogous to the loss in pressure due to the friction encountered by water flowing through a pipe line.

If, in the illustration just given, a size of wire were used such that its resistance would be .1 ohm per mile, it is evident that the loss in the line would be halved, but the weight of copper required doubled, because the wire would have to be double the cross-section. The question as to whether it would pay better to invest more money in the line or to put up with the larger loss is something that must be determined in each case by the relative cost of power and copper.

In many cases, the loss allowed in the line is about 10% of the power to be delivered, though sometimes the loss may be allowed to run as high as 15% or 25%. This applies only to transmission lines. For local electric-light or power-distributing systems, the amount of drop allowed is usually about 2% for the former and 5% for the latter.

The problem of calculating line wires usually presents itself in the following form: Given, a certain amount of power to transmit over a known

distance with a certain allowable loss, to determine the cross-section of the wire required.

P = power to be delivered, expressed in watts; P will be equal to horsepower delivered at end of line multiplied by 746; allowable percentage of loss in line, i. e., percentage of power delivered that may be lost in transmission; Let

E = voltage at end of line where power is delivered; C = current at full load;

L = length of wire through which current flows.

The cross-section of the copper conductor will then be given by the following formula:

 $A = \frac{10.8 \times L \times C \times 100}{100}$ (1)

A will be expressed in circular mils, and the corresponding size of wire may be found by consulting the wire table. It should be noticed, particularly, that in this formula. L is the average length of conductor through which the current C flows. The application of distance of transmission in the formula will be understood from what follows.

EXAMPLE.—A mine pump, driven by an electric motor, is situated 2 miles from the power station. The electrical input of the motor at full load is 50 H. P., and the voltage at its terminals is to be 500. Estimate the size of line wire necessary to supply the motor, the allowable loss in the line being

15% of the power delivered.

The actual length of line through which the current will flow will be 4 miles, because the current has to flow out to the motor and back again. We have

$$C = \frac{\text{watts}}{E} = \frac{50 \times 746}{500} = 74.6 \text{ amperes.}$$

Applying formula (1), we have

$$A = \frac{10.8 \times 2 \times 2 \times 5,280 \times 74.6 \times 100}{500 \times 15} = 226,880 \text{ circular mils, nearly.}$$

By consulting the wire table it is found that this calls for a wire a little larger than No. 0000, which has a cross-section of 211,600 circular mils; No. 0000 wire would probably be used in this case, as it is near enough to the calculated size for all practical purposes. In case the calculated size comes out larger than any size given in the table, a number of wires may be used in multiple to make up the required cross-section, or, what is better, a stranded cable may be used. These heavy stranded cables may now be obtained in different sizes, up to 2,000,000 circular mils cross-section.

It is evident that, in the above examples, if it were allowable to waste

twice as much power in the line, or what is equivalent to having a line drop of 150 volts instead of 75 volts, the cross-section of wire required would have been one-half of that found above. Such a large amount of loss would, however, be objectionable unless power was very cheap. A large drop in the line is in any case objectionable, because the voltage at the receiving end of the circuit will fall off greatly unless the voltage at the generating station is raised, as the load comes on, in order to compensate for the line drop. Most of the uses to which electricity is put, in mines or other places, drop. Most of the uses to which electricity is put, in mines or other places, requires that the pressure at the point where the power is utilized shall be kept approximately constant. For example, in the case of incandescent lights, the lamps will fall off greatly in brightness if the pressure decreases even by a comparatively slight amount. Also, if motors are being operated, the speed will vary considerably if the pressure is not kept constant, and it may be stated, in general, that a large line loss tends to poor regulation at the end of the circuit where power is delivered.

From the above considerations, it will be seen that, in the majority of cases the size of wire to be used under given conditions is determined by

cases, the size of wire to be used under given conditions is determined by current is to be used near at hand, the size of wire so determined might not be large enough to carry the current without overheating. Of course, in such cases, the safe carrying capacity of the wire determines the size to be used, and the drop will be correspondingly less.

and the drop will be the control of current that a given wire can carry without overheating mends very largely on the location of the wire. For example, a wire depends very largely on the location of the wire. strung in the open air will carry a greater current, with a given temperature rise, than the same wire would if boxed up in a molding or conduit. The

table on page 209 gives the approximate safe carrying capacity of wires

when strung in the air. In order to keep down the size of wire required to transmit a given amount of power over a given distance, with a certain allowable loss, the current must be kept as small as possible. Now, for a given amount of power, the current can only be made small by increasing the pressure, because the number of watts, or power delivered, is equal to the product of the current and the pressure. As a matter of fact, if the pressure in any given case be doubled, the amount of copper required will be only one-fourth as great; in other words, for a given amount of power transmitted, the weight of copper required decreases as the square of the voltage. It is at once seen, then, that if any considerable amount of power is to be trans-

or copper becomes prominiory. The use of high pressures in power transmission will be taken up in connection with alternating currents.

Insulated Wires.—For most overhead line work using modern voltages, weather-proof insulated wire is used. This wire is covered with two or three braids of cotton, and treated with insulating compound. For inside work, and in places where a better quality of insulation is required, rubber-covered wires are used. The following table gives the approximate weight of weather-proof line wire. The cost of the wire per pound varies considerably, owing to the variations in the price of copper; about 18 cents per pound may be taken as an approximate figure in making calculations.

mitted over long distances, a high line pressure must be used or else the cost of copper becomes prohibitory. The use of high pressures in power trans-

WEATHER-PROOF LINE WIRE (ROEBLING'S).

	Do	uble Braic	l.	Т	iple Braid	
Number. B. & S. Gauge.	Outside Diameter.	Weight.	Pounds.	Outside Diameter.	Weight.	Pounds.
	32ds Inch.	Per 1,000 Ft.	Per Mile.	32ds Inch.	Per 1,000 Ft.	Per Mile.
0000	20	716	3,781	24	775	4,092
000	18	575	3,036	22	630	3,326
, 00	17	465	2,455	18	490	2,587
. 0	16	375	1,980	17	400	2,112
1	15	285	1,505	16	306	1,616
$\frac{2}{3}$	14	245	1,294	15	268	1,415
3	13	190	1,003	14	210	1,109
4	11,	152	803	12	164	866
5	10	120	634	11	145	766
4 5 6 8	9 8 7	98	518	10	112	591
. 8	8	66	349	9	78	412
10	7	45	238	8	55	290
12	6	30	158	7	35	185
14	5	20	106	6	26	137
16	6 5 4 3	14	74	9 8 7 6 5	20	106
18	3	10	53	4	16	. 85

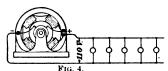
For high-tension lines, it is customary to use bare wires and insulate them thoroughly on special porcelain insulators. The ordinary weatherproof wire insulation is of little or no use as a protection when these high pressures are used, and it only makes the line more dangerous because of the appearance of false security that it gives. In many cases, it is also better to use bare feeders for mine-haulage plants, because the ordinary insulation soon becomes defective in a mine, and a wire in this condition is really more dangerous than a bare wire, because the latter is known to be dangerous and will be left alone.

CURRENT ESTIMATES.

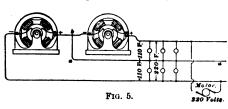
Before calculating the size of wire required for any given case, it is necessary to know the current, and the method of getting at this will depend on what the current is to be used for.

incandescent Lamps.—These are usually operated on 110-volt circuits, Fig. 4, or on the three-wire system, as shown in Fig. 5. In the three-wire system, two 110-volt dynamos are connected in series so that the voltage across the outside wires is 220. The neutral

wire a a connects to the point b where the machines are connected together. The wire a a merely serves to carry the difference in the currents on the two sides of the system, in case more lamps should be burning on one side than on the other. The outside wires for such a system are calculated as if the lights were operated



two in series across 220 volts. The middle wire is usually made equal in size to the outer wires. An ordinary 16 c. p. incandescent lamp requires about 55 watts for its operation; a 32 c. p. lamp requires about 110 watts.



Hence, in the case of ordinary parallel distribution, as shown in Fig. 4, the dy-namo will deliver about 1 ampere for each 16 c. p. lamp operated, and 1 ampere for each 32 c. p. lamp. In the case of the three-wire system, each pair of 16 c. p. lamps will take

total number of amperes in the outside wires will be one-fourth the number of lamps operated.

EXAMPLE.—A certain part of a mine is to be illuminated by fifty 16 c. p. lamps and ten 32 c. p. lamps. This portion of the mine is 1,000 ft. from the dynamo room, and the allowable drop in pressure is 54. The lamps are to be run on a 110-volt system. Find the size of wire required.

We have, then,

circular mils = $\frac{10.8 \times 1,000 \times 2 \times 35 \times 100}{1000 \times 1000} = 137,454$ circular mils. 110×5

or about a No. 00 B. & S. wire.

EXAMPLE.—Take the same case as in the last example, but suppose the lights to be operated on the three-wire system. There will then be twenty-five 16 c. p. lamps and five 32 c. p. lamps on each side of the circuit, and the total current in the outside wires will be 17.5 amperes. The voltage between the outside wires will be 220, and we will have

circular mils = $\frac{10.8 \times 1,000 \times 2 \times 17.5 \times 100}{2000 \times 1000}$ = 34.363 circular mils.

or about a No. 5 B. & S. wire.

If we make the central wire also of this size, it is seen that this system would require three-eighths the amount of copper called for by the plain 110-volt system. There is the disadvantage that two dynamos are needed. NOTE.—The length to be used in the wiring formula is the average dis-

tance traversed by the current in the conductor. For example, if, as in Fig. 6 (a), the lamps were all grouped or bunched at the end of the line, the length used in the formula would be twice that from G to A, because the whole current has to flow out to A through one main and back through the other. In other words, the whole current here passes through the whole length of the line. In case the load is uniformly distributed all along the line, as shown in Fig. 6 (b), it is evident that the current decreases step by step from the dynamo to the end. In such a case, the length or distance to be used in the formula is one-half that used in the former case, or simply the distance from the dynamo to the end, instead of twice this distance.

Arc Lamps.—Arc lamps are frequently run on constant-potential circuits, and usually consume from 400 to 500 watts. There are so many types of these lamps that it is difficult to give any current estimates that will be generally applicable. Enclosed arc lamps usually take from 3 to 5 amperes when run on 110-volt circuits.

Motors.—Fractically all the motors used in mining work are run on the constant-potential system, either at 250 or 500 volts. The efficiency of ordinary motors will vary from 70% to 95% or higher, depending on the size. The efficiency is greater with the larger machines, and, for the ordinary run of motors, it will probably lie between 80% and 90%. By efficiency is here meant the ratio of the useful output at the pulley or pinion of the motor to the total input. The accompanying table gives the efficiency of motors of ordinary size:

APPROXIMATE MOTOR EFFICIENCY.

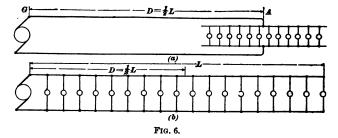
‡ to 1½ H. P., inclusive = 75% efficiency 3 to 5 H. P., inclusive = 80% efficiency 7½ to 10 H. P., inclusive = 85% efficiency 15 H. P. and upwards = 90% efficiency

If the required output in horsepower is known, the input will be

$$W = \frac{\text{H. P.} \times 746}{\text{efficiency}},$$

and the current required at full load will be $C = \frac{W}{E}$, where E is the voltage between the mains at the motor.

Conductors for Electric-Haulage Plants.—In electric-haulage plants, the rails take the place of one of the conductors, so that, in calculating the size of feeders required, only the overhead conductors are taken into account. It is a difficult matter to assign any definite value to the resistance of the track circuit, as it depends very largely on the quality of the rail bonding at the



joints. If this bonding is well done, the resistance of the return circuit should be very low, because the cross-section of the rails is comparatively large. For calculating the supply feeders, we may use the approximate formula,

circular mils =
$$\frac{14 \times L \times C \times 100}{E \times \% \text{ drop}}$$
.

In this case, L is the average length of feeder over which the power is to be transmitted. It will be noticed that the constant 10.8 appearing in the previous formulas has here been increased to 14. This has been done to allow, approximately, for the track resistance, but this constant might vary considerably, depending on the quality of the rail bonding. If the load is all bunched at the end of the feeder, L is the actual length of the feeder in feet. If the load is uniformly distributed all along the line, as it would be if a number of locomotives were continually moving along the line, the distance L in the above formula would be taken as one-half that used in the case where the load was bunched at the end. In other words, the whole current C would only flow through an average of one-half the length of the line.

EXAMPLE.—In Fig. 7, a b represents a section of track 4,000 ft. long. From the **dynamo** c to the beginning of the section, the distance is 1,200 ft. The trolley wire is No. 00 B. & S., and is fed from the feeder at regular intervals. Two mining learner traces are constant as a and a are a. EXAMPLE.—In Fig. 7, a b represents a section of track 4,000 ft. long. Two mining locomotives are operated, each of which takes an average current of 75 amperes. The total allowable drop to the end of the line is to be 5% of the terminal voltage, which is 500 volts. Calculate the size of feeder required, assuming that the constant 14, in the formula, takes account of the resistance of the return circuit.

Since the locomotives are moving from place to place, the center of distribution for the load may be taken at the center of the 4,000 ft. The

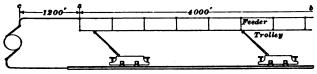


FIG. 7.

distance L will then be 1.200 + 2.000 = 3.200 ft. The total current will be 150 amperes; hence, we have

circular mils =
$$\frac{14 \times 3,200 \times 150 \times 100}{500 \times 5}$$
 = 268,800.

This would require either a stranded cable or the use of two No. 00 wires in parallel from c to a. From a to b we have the No. 00 trolley wire in parallel with the feeder; hence, the section of feeder ab may be a single No. 00 wire. In many cases, the drop is allowed to run as high as 10%, because the loads are usually heavier, and the distances longer, than in the example given above.

DYNAMOS AND MOTORS.

A dynamo is a machine for converting mechanical energy into electrical

energy by moving conductors relatively to a magnetic field.

An electric motor is a machine for converting electrical energy into mechanical energy by the relative motion between conductors carrying a

current and a magnetic field.

In the case of a dynamo, a number of conductors are made to move across a magnetic field by means of a steam engine or other prime mover, and the result is that an E. M. F. is set up in the conductors, and this E. M. F. will set up a current if the circuit is closed.

In the case of a motor, a number of conductors are arranged so that they are free to move across a magnetic field, and a current is sent through these through these conductors reacts on the magnetic field and causes the conductors to move, thus converting the electrical energy delivered to the motor into mechanical energy.

As far as mechanical construction

As far as mechanical construction goes, dynamos and motors are almost identical, and the operation of the motor is exactly the reverse to that of the

dynamo.

Dynamos and motors may be divided into two general classes: (a) Dynamos and motors for direct current; (b) dynamos and motors for alternating current.

DIRECT-CURRENT DYNAMOS.

Principle of Action.—Direct-current dynamos are those that furnish a current that always flows in the same direction. This kind of dynamo is largely used for incandescent lighting, and also for the operation of street railways.

A dynamo generates an E. M. F. by the motion of conductors across a magnetic field; hence, at the outset, it is seen that there must be at least two essential parts to a dynamo; namely, a magnet of some kind to set up a magnetic field, and a series of conductors arranged so that they may be moved or revolved in the magnetic field. The first part is known as the field magnet, or very often, simply as the field. The second part is known as the armature. The field is supplied by means of a powerful electromagnet which is magnetized by the current in the field coils. Fig. 8 shows a typical six-pole magnet of this kind; B, B are the magnetizing coils, which, when a current is sent through them, form powerful magnetic poles at N. 5. The framework A of such a field magnet is usually made of east iron or cast steel.



Fig. 8.

These field magnets may have any number of poles, but machines of ordinary size are usually provided with from two to eight poles.

The armature usually consists of a number of turns of insulated copper wire, arranged around the periphery of a ring or drum built up of soft iron sheets. Fig. 9 shows the construction of a typical armature of the ring type. The winding is divided into a number of sections, and the terminals connected to the commutator.

This commutator consists of a number of copper bars, insulated from each other by means of mica, the bundle of bars being clamped firmly into place and turned up to form a true cylindrical surface. The sections in the commutator correspond with those in the armature, and the use and operation of the

commutator will be described later. The winding on the ring is endless, i. e., it consists of a number of coils or sections c, the end of one section

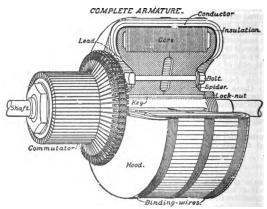
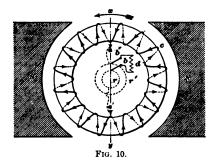


Fig. 9.

being joined to the beginning of the next, thus forming an endless coil, as shown in Fig. 10. The construction of such a ring armature would be as shown in Fig. 9.

Suppose the ring shown in Fig. 10 with its endless winding to be rotated between the poles of a 2-pole field magnet. We will then have the condition of affairs as indicated in Fig. 10. The magnetic lines will flow from the N pole of the field magnet across through the iron core of the armature and enter the S pole on the other side. Since all the conductors on the right-hand face of the ring are moving upwards, they will have an E. M. F. generated in them in one direction, while the E. M. F. in the conductors on the left side will have an E. M. F. in the opposite direction, because all the

conductors on this side are moving downwards, or in the opposite direction, to those on the other side. These two opposing E. M. F.'s will meet at a, as shown by the arrowheads, and will neutralize each other so that no current will flow through the windings of the armature. Suppose, however, that taps are connected at the points a and a', as shown by the dotted lines, and these taps connected to two ringsr, r', mounted so as to revolve with the armature. By allowing brushes b, b' to press on these rings we can make



these rings, we can make connection with an outside circuit d, which may consist of a number of lamps or any other device through which we wish to send a current. By putting in the taps at a and a', we have allowed the two opposing E. M. F. to set up a current through the common connections to the rings, and thence through the outside circuit. Current now flows in each half of the armature winding, unites at a, flows out by means of ring r' and both b', thence through the outside circuit d to brush b and ring r, from whence it passes to a', and thus completes the circuit. When the ring makes a half revolution from the position shown in the figure, it is seen that the current in the ouside circuit will flow in the opposite direction. In fact, an arrange ment of this kind would deliver a current that would be periodically revers-

ing in the outside circuit, or it would be what is known as

an alternating current.

Fig. 11.

Instead of simply bringing out two term in als to rings, suppose the winding to be tapped at a fairly large number of points, and connections brought down to a number of insulated strips, as shown in Fig. 11. If the armature be now revolved, it is seen that the brushes will come in contact with successive bars and keep the outside circuit in such relation to the armature winding that the current will always flow through it in the same direction. Moreover, if the number of divisions in the armature be large, the current will fluc-

tuate very little, being nearly as steady as that obtained from a battery. The arrangement made up of insulated bars is called the commutator, because it commutes or changes the relation of the outside circuit to the armature winding so that the current in the outside circuit always flows in the same direction. All practical machines used for the generation of direct current must be provided with such a commutator. When alternating currents are used it is only necessary to use plain collector rings, as

shown in Fig. 10. The foregoing brief description will give a general idea as to the construction of an ordinary direct-current dynamo or motor. Drum-wound armatures are more frequently used than the ring type shown,

but the action is the same in either case.

Factors Determining E. M. F. Generated.—A dynamo should be looked upon as a machine for maintaining an electrical pressure rather than as a machine for generating a current. A pump does not manufacture water—it merely maintains a head or pressure that causes water to flow wherever an outlet is provided for it to flow through. In the same way, a dynamo maintains a pressure, and this pressure will set up a current whenever the circuit is closed, so that the current can flow. The important thing to consider, therefore, is the E. M. F. that the dynamo is capable of generating.

The E. M. F. generated by an armature depends on the total number of presented lines but through pur second by the armature conductors. This

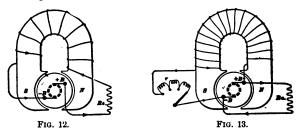
agnetic lines cut through per second by the armature conductors. This means that, in the first place, the faster the armature runs, the higher will be the E. M. F.; in the second place, the greater number of conductors or turns there are on the armature, the higher will be the E. M. F.; and in the third place, the stronger the magnetic field, the higher will be the E. M. F. The

E. M. F. in terms of these quantities may be written

n CN $E = \frac{100,000,000}{100,000}$

n = speed in revolutions per second; where

C = number of conductors on face of the armature; N = number of magnetic lines flowing from one pole.The constant 100,000,000 is necessary to reduce the result to volts. equation enables us to make calculations relating to any two-pole dynamo, and with slight modification it is applicable to machines with field magnets



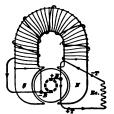
having a number of poles. It will not be necessary to consider this formula further here, as the main thing to fix in mind is that the E. M. F. is proportional to the three quantities: speed, number of conductors, and strength of

field.

Field Excitation of Dynamos. - In the earliest form of dynamo, the magnetic field in which the armature rotated was set up by means of permanent magnets. Permanent magnets are, however, very weak compared with electromagnets, which are excited by means of current flowing around coils of wire wound on a soft-iron core, as shown in Fig. 13. As soon as the current ceases flowing around the coils of an electromagnet, the magnetism almost wholly disappears, but a small amount, known as the residual magnetalmost wholly disappears, but a small amount, known as the resultat magnetism remains. It is to this residual magnetism that the dynamo owes its ability to start up of its own accord and excite its own field magnets. When the armature is first started to revolve, a very feeble E. M. F. is generated in it, but the armature is connected to the field coils in such a way that this small E. M. F. is able to force a small current through the field coils, and thus set up a larger amount of magnetism in the field. This in turn increases the E. M. F. in the armature, and the building-up process good residity until the dynamo generates its full pressure. There are three on rapidly until the dynamo generates its full pressure. There are three different methods in use for supplying the field coils with current, and continuous-current dynamos are divided into three classes, according to the method used for exciting their fields. These three classes are: (a) Serieswound dynamos; (b) shunt-wound dynamos; (c) compound-wound dynamos.

(a) Series-Wound Dynamos.—In this class of machine, the field coils are Innected in series with the armature, and all the current that passes.

This arrangement is shown in Fig. 12, where N This arrangement is shown in Fig. 12, where N and S represent the poles of the magnet, +B and S represent the poles of the magnet, +B and -B the brushes, and Re the outside circuit, which may consist of lamps, motors, or any other device in which it is desired to utilize the current. It will be noticed that with arrangement of this kind, the E. M. F. will increase as the current increases, because the tield will become stronger and the speed is supposed to remain constant. This will be true upto the point where the field carries all the magnetism it is capable of, or, in other words, until the becomes saturated. After this point is reached, the E. M. F. will increase very little with increase of current. In most of the with increase of current. In most of the



Work connected with lighting or power transmission, it is desirable to have the voltage

remain nearly constant. For this reason, therefore, the series method of

excitation has not been very largely used for dynamos. The only style

of generator to which it has been applied at all generally is the are-light dynamo, and these machines are provided with an automatic regulator of some kind to vary the voltage as desired. The series field winding has, however, been largely used in connection with the motors operated on constant-pressure circuits, as will be taken up later in connection with motors.

- (b) Shunt-Wound Dynamos.—This style of machine has not been used largely of late years, although it was formerly very common. Its use is at present confined more particularly to machines of small size. In this method of excitation, the field is connected as a shunt or by-pass to the armature; i.e., the field winding is connected in parallel with the armature. This winding consists of a large number of turns of fire wine so that its armature; i. e., the field winding is connected in parallel with the armature. This winding consists of a large number of turns of fine wire, so that its resistance is high and only a small part of the total current flows through it. Fig. 13 shows the connections for this kind of field excitation. An adjustable resistance is usually inserted in the field circuit, and by cutting this resistance in or out, the field may be weakened or strengthened and the voltage varied accordingly. With this type of machine, the current through the field does not vary greatly from no load to full load, and if the dynamo is well designed, the pressure at the brushes will keep approximately constant. The pressure will, however, always fail off more or less, on account of the drop in the armature, due to its resistance, and also upon the tendency that the current in the armature has of weakening the field. the tendency that the current in the armature has of weakening the field. The shunt winding is used quite largely for motors.
 - (c) Compound-Wound Dynamos.—The compound-wound dynamo is the one most largely used for direct-current power and light distribution, and it is so called because the winding used for exciting the field is a combination of the series and shunt windings previously described. The series winding series and shunt windings previously described. The series winding serves the purpose of keeping up the field strength while the load is increased, and thus keeps the pressure constant, or even makes it rise with increased load, if so desired. When the series winding is so adjusted that the pressure rises as the load is increased, the machine is said to be overcompounded. Fig. 14 shows the connections for such a machine. It will be seen that the shunt winding is connected as before, a field resistance or rheostat, not shown in the figure, being inserted for the purpose of adjusting the volt-One brush connects directly to one terminal of the machine +T, while the other brush connects to one end of the series winding on the field. other end of the series winding forms the other terminal -T, to which the outside circuit R e is connected. It is thus seen that the shunt coil supplies a certain amount of initial magnetization that is augmented by the magnetism supplied by the series coils. Of course, care must be taken to see that the current in the series coils circulates around the field in the same direction as that in the shunt coils, otherwise the effect would be to make the E.M. F fall off with increasing load instead of keeping it up. This is the style of dynamo used almost exclusively for electric haulage plants, as well as plants for direct-current illuminating purposes.

DIRECT-CURRENT MOTORS.

Direct-current motors are in general almost identical, so far as constructions goes, with direct-current dynamos. Motors are often required to operate under very trying conditions, as for example, in mine haulage or pumping plants or on the ordinary street car. For this reason, their mechanical construction often differs somewhat from that of the dynamo, the design being modified in such a way as to enclose the working parts as completely as possible, and thus protect them from dirt and injury. The two kinds of motors most commonly used are the series and shunt varieties. Compound-wound motors are only used for a few special kinds of work. Practically all of the motors in use are operated from constant-pressure mains; i. e., the pressure at the terminals of the motor is practically constant, no matter what load it may be carrying. We will here consider constant-potential motors only.

Principles of Operation.—If the fields of an ordinary constant-potential dynamo are excited and a current supplied to the armature from some outside source, such as another dynamo D, Fig. 15, so that the current enters

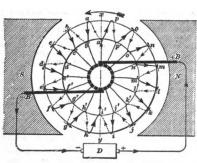


Fig. 15.

o, so that the current enters at + B, and passing through the winding in the direction in dicated by the arrowheads, leaves at brush - B, it will be found that all of the conductors under the S pole face, b, c, d, e, f, and g, will tend to move downwards, and all those under the N pole face, j, k, l, m, n, and o, will tend to move upwards, as indicated by the small arrawing through the small arra

by the small arrows.

These forces combine to produce a tendency of the armature to rotate about its axis as indicated by the large arrows, which tendency is called the torque

of the motor.

The amount of this torque—which is usually

expressed in pound-feet; that is, a certain number of pounds acting at a radius of a certain number (usually 1) of feet—depends on (1) the strength of the field, (2) the number of conductors, (3) their mean distance from the axis of the armature, and (4) the amperes in each conductor. In any given machine, the second and third conditions are constant, so that the torque depends on the strength of the field and the current.

If the armature is stationary, the E. M. F. required to send the current through the winding is only that necessary to overcome the drop, which is due to the resistance of the winding. If the torque exerted by this current is greater than the opposition to motion, so that it causes the armature to revolve, the motion of the conductors through the field generates in them an E. M. F. that is opposed to the E. M. F. that is sending the current through the armature.

This opposing E. M. F., or counter E. M. F. as it is called, then diminishes the effect of the applied E. M. F., so that the current is reduced, reducing the torque. Should the torque still be greater than the opposition to motion, the speed of the armature will continue to increase, increasing the counter E. M. F., and thereby further reducing the current and the corresponding torque, until the torque just balances the opposition to the motion, when the speed will remain constant.

At all times the drop of potential, through the agreeting is cared to the

At all times, the drop of potential through the armature is equal to the difference between the counter and the applied E. M. F.'s, and as the product of this drop and the current represents energy wasted, it is desirable to make it as low as possible. In good motors of about 10 H. P. output, the drop in the armature is seldom more than about 5% of the applied E. M. F., and is less in larger machines.

This being the case, it is evident that if the armature is at rest, so that it

as no counter E. M. F., and is connected directly to the mains, a very large arrent will flow through it, which would be liable to damage the armature, this account an external resistance, called a starting resistance, is connected in series with the armature when it is to be started. This resistance a made great enough to prevent more than about the normal current from lowing through the armature when it is at rest; as the armature speeds up and develops some counter E. M. F., this resistance is gradually cut out. intil the armature is connected directly to the mains, and is running at ormal speed.

The energy represented by the product of drop in the armsture and the current is wasted; that represented by the product of the current and the counter E. M. F., that is, the counter E. M. F., is the energy required to teep the armature in motion.

Aside from the comparatively small amount of current required to furnish he torque necessary for overcoming the frictional losses in the motor itself, which are practically constant, the amount of current taken from the mains s directly proportional to, and varies automatically with, the amount of the external load; for, if this external load is increased, the current which has been flowing in the armature cannot furnish sufficient torque for this increased load, so that the machine slows down. This decreases the counter E. M. F., which immediately allows more current to flow through the armature, increasing the torque to the proper amount. If the external load is decreased, the current flowing furnishes an excess of torque, which causes the speed to increase, increasing the counter E. M. F., and decreasing the current until it again furnishes only the required amount of torque.

Since the counter E. M. F. is very nearly equal to the applied, it is only necessary for it to vary a small amount to vary the current within wide limits. For example, if the resistance of a certain armature is 1 ohm, and it is supplied with current at a constant potential of 250 volts, then, when a current of 10 amperes is flowing through it, the drop is $10 \times 1 = 10$ volts and the counter E. M. F. is 250 - 10 = 240 volts. Now, if the current is reduced to 1 ampere, the drop is $1 \times 1 = 1$ volt, and the counter E. M. F. is

250-1=249 volts; that is, the counter E. M. F. only varies $\frac{9}{240}$, or 3.75%, while the current varies $\frac{9}{10}$, or 90%.

As stated before, the field magnets of constant-potential motors are

usually either shunt-wound or series-wound.

If shunt-wound, and supplied from a constant-potential circuit, the magnetizing force of the field coils is constant, giving a practically constant field. This being the case, the counter E. M. F. is directly proportional to the speed, so that variations of the load make only slight variation in A shunt-wound motor is then (practically) a constant-speed the speed. motor.

With series-wound motors, the strength of the field varies with the current; if the load on such a motor is reduced, the excess of torque makes the armature speed up, but as the resulting decrease of the current decreases strength up, but as the resulting decrease of the current decreases the field strength, the armature must speed up to a much greater extent, in order to increase the counter E. M. F. to the right degree, than would be necessary if the field were constant. If the load is increased, the increase in the current so increases the field strength that the speed must decrease considerably, in order to decrease the counter E. M. F. by the right amount. The speed of a series-wound motor, then, varies largely with variations in the load.

An advantage of the series motor is that if a torque greater than the normal is required, it can be obtained with less current than with a shunt motor, since the increased current increases the field strength, and the torque is proportional to both these factors.

It would not be practicable to make the field strength of a shunt motor as great as is possible to get with a series motor, since it would require a very large magnetizing force, and with the shunt winding, this extra magnetizing force would have to be expended all the time, whether the strong field was required or not, which would be very wasteful; in the series motor, however, this extra magnetizing force is only expended while it is needed.

A disadvantage of the series winding is that if all the load is taken of the current required to drive the motor is very small, making a weak field which requires such a high speed to generate the proper counter E. M. P. that the armature is liable to be damaged. In other words, the motor will race, or run away, if the load is all removed. This cannot occur with the

shunt motor as long as the field circuit remains unbroken.

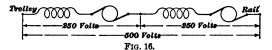
On account of the above features, shunt motors are used to drive machinery that requires a nearly constant speed with varying loads, or which would be damaged if the speed should become excessive, such as ordinary machinery in shops and factories, pumps, etc. Series motors are used on street cars, to operate hoists, etc., where, on account of the gearing used, the load cannot be entirely thrown off, and the torque required at starting and getting quickly up to speed is much greater than the normal

Speed Regulation of Motors.—The torque of a motor depends on the current; that is, for a given current, the torque will be the same whatever may be that is, for a given current, the torque will be the same whatever may be the speed, provided the field strength remains the same. The speed at which the armature runs is a matter of E. M. F. only; that is, with a given current the speed will be proportional to the applied E. M. F., or, more strictly, the counter E. M. F., other conditions remaining the same.

It has been shown that the torque will automatically regulate itself for changes in the load. The speed, however, may be varied by varying the applied E. M. F. or the strength of the field. A change in speed may or may not result in a change in the torque required, depending on the character of the work done by the motor.

character of the work done by the motor.

The simplest way to vary the applied E. M. F. is to insert a resistance, in series with the armature, similar to the starting resistance. By varying this resistance, the applied E. M. F. at the terminals of the motor is also varied, although the E. M. F. of the mains remains constant. It is evident



that the energy represented by the product of the current and the drop through the resistance is converted into heat, and is thereby wasted; therefore, for great variations in speed, this method is not economical, though often very convenient.

The applied E. M. F. may also be varied by varying the E. M. F. of the generator supplying the may also be varied by varying the E. M. F. of the

generator supplying the current, but this can only be done where a single generator is supplying a single motor, or several motors, whose speed must all be varied at the same time; so that this method is only used in special

If the strength of the field is changed, the speed necessary to give a certain counter E. M. F. will also be changed, which gives a convenient method of varying the speed. If the strength of the field is lessened, the speed will increase, and if the field is strengthened, the speed will decrease. With shunt motors, the field may be weakened by inserting a suitable resistance in the field circuit, as in shunt dynamos; with series motors the same result may be obtained by cutting out some of the turns of the field coils or by placing a suitable resistance in parallel with the field coils.

This method of regulation is also of limited range, since it is not econom-

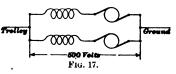
ical to maintain the strength of the field much above or below a certain The resistance method described above being rather more simple, density. it is generally used. For special cases, such as street-railroad work, various

special combinations of the above methods of regulation are used

One of the most common of these is known as the series-parallel method, and is the method of regulation generally used at present for operating street cars. This method is equivalent to the method of cutting down the speed by reducing the E. M. F. applied to the motor, and is only applicable where at least two motors are used. It is also used, to some extent, in haulage plants. When a low speed is desired, or when the car is to be started up, the motors are thrown in series, as shown in Fig. 16, thus making the voltage across each motor equal to one-half the voltage between the lines, and cutting down the speed accordingly. When a high speed is desired, the motors are thrown in multiple, as shown in Fig. 17, and each motor runs at full speed because it gets the full line pressure. In practice, starting resistances are used in connection with the above to make the starting smooth, but the two running positions are as shown, the motors being connected in series in the one case, and in parallel in the other.

Connections for Continuous-Current Motors.—Fig. 18 shows the manner in which a shunt motor is connected to the terminals + and — of the circuit, it will be seen that the current through the shunt field does not

through the shunt field does not Dass through the resistance R which is connected in the armacircuit. This is necessary, since to keep the field strength constant, the full difference of potential must be maintained between the terminals of the field coil, which would not be the case



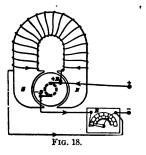
if the rheostat were included in the field current, for then the difference of potential would be only that existing between the brushes +B and -B. As on starting the motor this difference of potential is small, only a small current would flow through the field coils, which would generate such a weak field that an excessive current would be required to furnish the necessary torque for starting the motor.

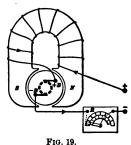
When connected as shown, however, the field is brought up to its full strength before any current passes through the armature; so this difficulty does not arise.

Since in a series motor the same current flows through both armature and field colls, the starting resistance may be placed in any part of the circuit. The diagram in Fig. 19 illustrates one method of connecting a series motor to the line terminals + and —; here the starting or regulating resistance R is placed between the — line terminal and the brush —B of the motor.

To reverse the direction of rotation of a motor it is necessary to reverse either the direction of the direction of the current through the armature. It is usual to reverse the direction of the current in the armature in the strength of the current in the armature.

ture, a switch being used to make the necessary changes in the connections. Fig. 20 shows the connections of one form of reversing switch. Two metal bars B and B, are pivoted at the points T and T; one is extended and supplied with a handle H, and the two bars are joined together by a link L of some insulating material, such as fiber. Three contact pieces a, b, and c are arranged on the base of the switch so that the free ends of the



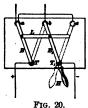


bars B and B_1 may rest either on a and b, as shown by the full lines, or on b and c, as shown by the dotted lines. The line is connected to the terminals T and T_1 , and the motor armsture between a and b, or vice versa, a and c being connected together.

When the switch is in the position shown by the full lines T is connected to a by the bar B, and T, to b by the bar B. If the switch is thrown by means of the handle H into the position indicated by the dotted lines, T is connected to b by the bar B, and T1 to a by the bar B1 and the connection

between c and a. The direction of the current through the motor armature, or whatever circuit is connected between a and b, is thus reversed.

In order to reverse only the current in the armature, the reversing switch must be placed in the armature circuit only. Fig. 21 represents the connec-



tion for a reversing-shunt motor (a) and a reversing-series motor (b); + and — are the line terminals; R, the starting resistance; B and B, the brushes of the motor, and F, the field coll of the motor. Some manufacturers combine the starting resistance and reversing switch in one piece of apparatus.

In connecting up motors, some form of main switch is used to entirely disconnect the motor from the line

when it is not in use.

To prevent an excessive current from flowing through the motor circuit from any cause, short strips of an easily melted metal, known as fuses, mounted on suitable terminals, known as fuse boxes, are placed in the circuit. These fuses are made of such a sectional area that a current greater than the normal heats

them to such an extent that they melt, thereby breaking the circuit and preventing damage to the motor from an excessive current. The length of fuse should be proportioned to the voltage of the circuit, a high voltage requiring longer fuses than a low voltage, in order to prevent an arc being maintained across the terminals when the fuse melts.

If desired, measuring instruments (ammeter and voltmeter) may be connected in the motor circuit, so that the condition of the load on the motor may be observed while it is in operation. All these appliances, regulating resistance, reversing switch, fuses, instruments, etc., are placed

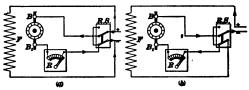


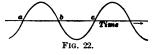
Fig. 21.

inside the main switch; that is, the current must pass through the main switch before coming to any of these appliances, so that opening the main switch entirely disconnects them from the circuit, when they may be handled without fear of shocks.

ALTERNATING-CURRENT DYNAMOS.

An alternating-current dynamo is one that generates a current that periodically reverses its direction of flow. It was shown in connection with Fig. 10 that an armature provided simply with collector rings produced an alternating current in the outside circuit. This current may be represented by a curve such as that shown in Fig. 22.

The complete set of values that the current or E. M. F. passes through repeatedly is known as a cycle. example, the values passed through during the interval of time represented by the distance ac would constitute a cycle. The set of values passed through during the interval ab is

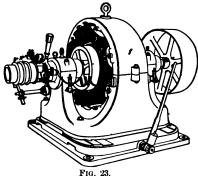


known as an alternation. An alternation is, therefore, half a cycle. The number of cycles passed through per second is known as the frequency of the current, or E. M. F.

Alternating-current dynamos are now largely used both for lighting and power transmission, especially when the transmission is over long distances. The reason that the alternating current is specially suitable for long-distance work is that it may be readily transformed from one pressure to another. We have already seen that in order to keep down the amount of copper in the line, a high line pressure must be used. Pressures much over 500 or 600 to down the cannot be readily generated with direct-current machines, owing to the troubles that are likely to arise due to sparking at the commutator. On the other hand, an alternator requires no commutator or even collecting rings, if the armature is made stationary and the field revolving, as is frequently done. Alternators are now built that generate as high as 8,000 or 10,000 volts directly. If a still higher pressure is required on the line, it can be easily obtained by the use of transformers, to be explained later. It is thus seen that where power is to be carried over long distances, the alternating current is indispensable.

Alternating-current dynamos, like direct-current machines, consist of two main parts, i. e., the field and armature. Either of these parts may

be the revolving member, and in many modern machines the armature, or the part in which the current is induced, is the revolving member. Fig. 23 shows a typical alternator of the belt-driven type, having a revolving armature. It is not unlike a direct-current machine as regards its general appearance. The eral appearance. number of poles is usually large, in order to secure the required frequency without running the machine at a high rate of speed. The frequencies met with in practice vary all the way from 25 to 150. The higher frequencies number of poles is usually The higher frequencies are, however, passing out of use, and at present a



frequency of 60 is very common. This frequency is well adapted both for power and lighting purcommon. This frequency is well adapted both for power and lighting work frequency. When machines are used almost entirely for lighting work, frequencies of 125 or higher may be used. The frequency of any machine may be readily determined when the number of poles and the speed is known, as follows:

Frequency =
$$\frac{\text{number of poles}}{2} \times \frac{\text{rev. per min.}}{60}$$
.

For example, if an eight-pole alternator were run at a speed of 900 R. P. M., the frequency would be

 $f = \frac{8}{2} \times \frac{900}{60} = 60$ cycles per second.

Alternators may be divided into the two following classes: (a) Single-phase alternators; (b) Multiphase alternators.

(a) Single-Phase Alternators.—These machines are so called because they generate a single alternating current (as represented by the curve shown in Fig. 22). The armature is provided with a single winding and the two terminals are brought out to collector rings, as previously described. Singlephase machines have been largely used in the past for lighting work, but they are gradually being replaced by multiphase machines, because the single-phase machines are not well suited for the operation of alternatingcurrent motors.

b) Multiphase Alternators.—These machines are so called because they deliver two or more alternating currents that differ in phase; i. e., when one current is, say, at its maximum value, the other currents are at some other value. This is accomplished by providing the armature with two or more distinct windings which are displaced relatively to each other on the armature. One set of windings, therefore, comes under the poles at a later instant than the winding ahead of it, and the current in its winding comes to its maximum value at a later instant than the current in the first wixed

ing. In practice, the two types of multiphase alternator most commonly used are (1) two-phase alternators, (2) three-phase alternators.

Two-phase alternators are machines that deliver two alternating currents. we-phase atterators are machines that deliver two alternating current that differ in phase by one-quarter of a complete cycle; i. e., when the current in one circuit is at its maximum value, the current in the other circuit is passing through its zero value. By tapping four equidistant points of a regular ring armature, as shown in Fig. 24, and connecting these points to four collector rings, a simple two-pole two-phase alternator is obtained. One circuit connects to rings 1 and 2. It is easily seen from the figure that when the part of the winding connected to one pair of rings is in its registion of maximum action the connected to one pair of rings is in its position of maximum action, the E. M. F. in the other coils is zero, thus giving two currents in the two different circuits that differ in phase by one-quarter of a cycle or one-half an alternation.

Three-phase alternators are machines that deliver three currents that differ in phase by one-third of a complete cycle; i. e., when one current is flowing in one direction in one circuit, the currents in the other two circuits are onehalf as great, and are flowing in the opposite direction. By tapping three equidistant points of a ring winding, as shown in Fig. 25, a simple three-phase two-pole alternator is obtained. Three mains lead from the collecting

rings.

In order to have three distinct circuits, it would ordinarily be necessary to have six collecting rings and six circuits; but this is not necessary in a three-phase machine if the load is balanced in the three different circuits, because one wire can be made to act alternately for the return of the other

Uses of Multiphase Alternators.—Multiphase alternators are coming largely into use, because, by using them, alternating-current motors can be readily operated. By using multiphase machines, motors can be operated that will

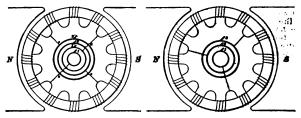


Fig. 24.

FIG. 25.

start from rest under load, whereas with single-phase machines the motor has to be brought up to speed from some outside source of power before it can be made to run. For this reason, such machines are used for the operation of modern power-transmission plants. As far as the general appearance of three-phase machines goes, they are similar to ordinary single-phase alternators, the only difference being in the armature winding and the larger number of collector rings. The multiphase alternator is also adapted for the operation of lights, so that by using these machines, both lights and motors may be operated from the same plant. They are well adapted for power-transmission purposes in mines, especially for the operation of pumping and hoisting machinery, because the motors operated by them are very simple in construction and therefore not liable to get out of order.

ALTERNATING-CURRENT MOTORS.

Alternating-current motors may be divided into two general classes:
(a) Synchronous motors; (b) Induction motors.
(a) Synchronous motors are almost identical, so far as construction goes.

with the corresponding alternator. For example, a two-phase synchronous motor would be constructed in the same way as a two-phase alternator.

nism, or in step, with the alternator driving them. This means that the motor runs at the same frequency as the alternator, and if the motor had the same number of poles as the alternator, it would run at the same speed, no matter what load it might be carrying. This type of motor has many good points, and is especially suited to cases where the amounts of power to be transmitted are comparatively large and where the motor does not have to be started and stopped frequently. Multiphase synchronous motors will start up from rest and will run up to synchronous speed without aid from any outside source. They will not, however, start with a strong starting torque or effort, and will not, therefore, start up under load, and cannot be used in places where a strong starting effort is required. For this

reason synchronous motors are not suitable for intermittent work. (b) Induction motors are so called because the current is induced in the

They are called synchronous motors because they always run in synchro-

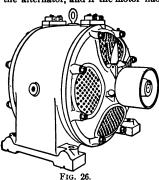
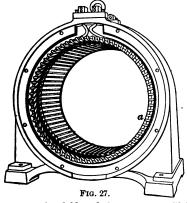


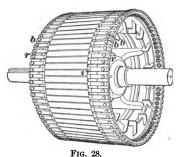
Fig. 26 shows armature instead of being led into it from some outside source. a typical induction motor. There are two essential parts in these machines, viz., the field, into which multiphase currents are led from the line, and the armature, in which currents are induced by the magnetism set up by the field. Either of these parts may be the stationary or revolving member, but in most cases the field, or part that is connected to the line, is stationary. Fig. 27 shows the construction of the stationary member or field. This consists of a number of iron laminations, built up to form a core and provided with slots around the inner periphery. The form-wound coils constituting the field winding are placed in these slots and connected to the mains. This winding is arranged in the same way as the armature winding of a multiphase alternator. When the alternating currents differing in phase are sent through the winding, magnetic poles are formed at equidistant points around the periphery of the field, and



the constant changing of the currents causes these poles to shift around the ring, thus setting up what is known as a revolving magnetic field. This armature, Fig. 28, consists of a laminated iron core provided with a number of slots, in each of which is placed a heavy copper bar b. The ends of these bars are all connected together by two heavy shortcircuiting rings r, r running around each end of the arma-The bars and end rings thus form a number of closed circuits. When such an armature is placed in the revolving field, the magnetism will cut across the armature conductors, inducing E. M. F.'s in them, and since the conductors are joined up into closed circuits, currents will flow in them. These currents will

react on the field, and the armature will be forced to revolve. Such an armature will not run exactly in synchronism, because if it did, it would revolve just as fast as the magnetic field, and there would be no cutting of lines of force. The speed drops slightly from no load to full load, but if the motor is well designed, this falling off in speed is slight.

Induction motors possess many advantages for mine work. One of the chief of these is the absence of the commutator or any kind of sliding con-



tacts whatever. Such motors can therefore operate with absolutely no sparking—a desirable feature for mine work. The motors are also very simple in construction, and are therefore not liable to get out of order. They have an additional advantage over the synchronous motor in that they start up with a strong starting effort, and, in fact, behave in most respects like any good shunt-wound direct-current motor. They are direct-current motor. They are used quite successfully for all kinds of stationary work, such as pumping, hoisting, etc., but so far have not been used to any great extent for haulage purposes. When these motors are used for purposes where a variable speed is

required, it is customary to provide the armature with a winding similar to that of the field and bring out the terminals to collecting rings, so that resistance may be inserted in the armature circuit.

TRANSFORMERS.

Reference has already been made to the use of transformers for changing an alternating current from a higher to a lower pressure, or vice versa, with a corresponding change in current. Transformers used for raising the voltage are known as step-up transformers; those used for lowering the pressure are known as step-down transformers.

The transformer consists of a laminated iron core upon which two coils These coils are entirely distinct, having no connection of wire are wound. with each other. One of these coils, called the *primary*, is connected to the mains; the other coil, called the *secondary*, is connected to the circuit to which current is delivered. Fig. 29 shows the arrangement of coils and core

for a common type of transformer. The secondary coil is wound in two parts S, S', and the primary coil, also in two parts P, P',

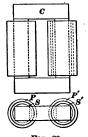


Fig. 29.

is placed over the secondary. C is the core, built up of thin iron plates. Fig. 30 shows a weather-proof cast-iron case for this transformer. When a current is sent through the primary it sets up a magnetism in the core which rapidly alternates with changes in the current. This changing magnetism sets up an alternating E. M. F. in the secondary, and this secondary E. M. F. depends



Fig. 30.

upon the number of turns in the secondary coil. If the secondary turns are greater than the primary, the secondary E. M. F. will be higher than that of the primary. The relation between the primary E. M. F. and secondary E. M. F. is given by the following:

or, secondary E. M. F. = primary E. M. F. primary turns secondary turns

The ratio primary turns is known as the ratio of transformation of the transformer.

For example, if a transformer had 1,200 primary turns and 60 secondary turns, its

mary turns and 60

secondary turns, its
ratio of transformation would be 20 to 1,
and the secondary

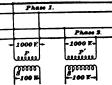
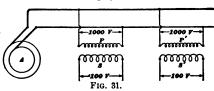


Fig. 32

voltage would be one-twentieth that of the primary. Transformers are made for a number of different ratios of transformation, the more common ones being 10 to 1 or 20 to 1. Of course, a transformer never gives out quite as much power from the secondary as it takes in from the primary mains, because there is always some loss in the iron core and in the wire making up the coils. The efficiency



of transformers is, however, high, reaching as high as 97% or 98% in the larger sizes. Transformers are always connected in parallel across the mains, and if they are well designed, will furnish a very nearly constant secondary pressure at all loads, when furnished with a constant primary pressure. Fig. 31 shows transformers connected on a single-phase circuit, Fig. 32 shows the connection for a two-phase circuit, and Fig. 33 shows one method of connection for a three-phase circuit.

ELECTRIC SIGNALING.

BATTERIES.

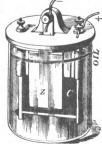
Batteries are used for various purposes in connection with mining work, principally for the operation of bells and signals.

The Leclanché cell is one that is widely used for bell and telephone work. It is made in two or

three different forms, one of the most common of these being as shown in Fig. 34 (a). The zinc element of this battery is in the form of a rod Z, and weighs about 3 oz. The other electrode is a carbon plate placed in a porous cup and suroxide of man mixed with black manganese, with crushed coke or carbon. The electrolyte used in the battery is a saturated solution of sal

FIG. 33.

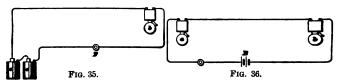




(b)

Fig. 34.

ammoniac. The E. M. F. of this cell is about 1.48 volts when the cell is in good condition. In another form of the cell, known as the *Gonda* type, the black oxide of manganese is pressed into the form of bricks and clamped against each side of the carbon plate by means of rubber bands. This cell will do good work if it is only used intermittently, i. e., on circuits where the insulation is good and where there is no leakage causing the cell to give

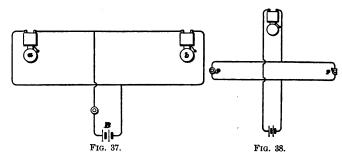


out current continuously. If current is taken from it for any length of time, it soon runs down, but will recuperate if allowed to stand.

In cases where the insulation is apt to be poor, as it often is in mines, it is best to use a battery that will stand a continuous delivery of current and that will at the same time operate all right on intermittent work or on work where the circuit is open most of the time. For work of this kind, cells of the Edison-Lalande or Gordon type are excellent. Fig. 34 (b) shows the Edison-Lalande cell. The elements consist of two zinc plates Z. hung on each side of a plate of compressed cupric oxide C. The electrolyte is a saturated solution of caustic potash, and this should be kept covered with a layer of heavy parafin oil, to prevent the action of the air on the solution. The voltage of the cell is only 7 volt, but its internal resistance is very low and its current capacity correspondingly large. The electrolyte used in the Gordon cell is also caustic-potash solution, and the two cells are much the same, so far as their general characteristics are concerned. The table on page 231 gives data relating to a number of different types of cell.

BELL WIRING.

The simple bell circuit is shown in Fig. 35, where p is the push button, be the bell, and c, c the cells of the battery connected up in series. When two or more bells are to be rung from one push button, they may be joined up

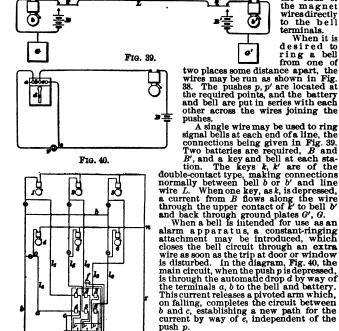


in parallel across the battery wires, as in Fig. 37 at a and b, or they may be arranged in series, as in Fig. 36. The battery B is indicated in each diagram by short parallel lines, this being the conventional method. In the parallel arrangement of the bells, they are independent of each other, and the failure of one to ring would not affect the others; but in the series grouping, all but one bell must be changed to a single-stroke action, so that each impulse of current will produce only one movement of the hammer. The current is then interrupted by the vibrator in the remaining bell, the result

						BAT	TER	IES.						231
Domerke	-	Polarizes rapidly.	For large currents.	Non-polarizing electrolyte. Cathode and depolarizer in porous cup.	Anode in porous cup.	Gravity cell. Resistance with sodium chloride, .5 ohm; with magnesium sulphate, 1 ohm.	forces cup used; pores become filled with ferric hydrate, an insoluble conductor.	Cathode and depolarizer in porous cup.	For closed-circuit work only; resistance 3 ohms.	Carbon and depolarizer in porous cup; resistance 4 ohms.	Surface of electrolyte covered with layer of oil.	Surface of electrolyte covered with layer of oil; resistance .07	Cathode and depolarizer in porous cups. For small currents.	For open or closed circuit working.
:	E. M.	e: 11.35 1.08	1.9 to 2	.78 1.89	2.14	1.9 to 2	2.7	1.07	1.07	1.48	۲.	.7	1.45	۲.
	Depolarizer.	None None None	Electrolyte	Nitric acid	Electropoion fluid diluted one-half	Bichromate solution(sulphochromic salt)		Copper sulphate with copper-sulphate crystals	Copper sulphate with copper-sul-	Peroxide of man-	Cupric oxide	Molded plates of cupric oxide and magnesic chloride held	urcopper names	Flaky copper oxide in perforated copper cylinder
	Cathode.	Copper Carbon	Carbon	Carbon Carbon	Carbon	Carbon	Carbon	Copper	Copper	Carbon	Iron or Copper.	Molded p	carbon	Flaky coprated co
	Electrolyte.	Sulphuric acid (dilute)Sulphuric acid (dilute)Sodium chloride (common salt)	Sulphuric acid 4 Potassium bichromate 3 Water 18	Ferric chloride Sulphuric acid (dilute	Sulphuric acid (very dilute) or \ water	Sodium chloride or magnesium sulphate	Caustic soda	Zinc sulphate	Zinc sulphate. Sp. Gr. 1.10 Copper	Ammonium chloride (saturated)	Caustic potash	Caustic potash	Sal ammoniae (ammonium chlo-ride)	Caustic soda
	Anode.	Zine Zine Zine	Zinc	Wrought iron Zinc	Amaiga- mated zinc in	mercury Zinc	Zinc	Zine	ravity Daniell Zinc	Zinc	Zine	Zine	Zine	Gordon Zine
	Name.	Volta Law	Grenet	Pabst Bunsen	Fuller	Partz	D'Arson- Zine	Daniell Zinc	Gravity Daniell	Leclan- ché	Lalande and	Chaperon Edison-Zinc	Chloride of mer-	Gordon

being that each bell will ring with full power. The only change necessary to produce this effect is to cut out the circuit-breaker on all but one bell by connecting

the ends of



shown in Fig. 42. The pushes 1, 2, 3, etc. are located in various places, one side being connected to the battery wire b, and the other to the leading wire l in communication with the annuation of two or three Leclanché cells is placed at B in any convenient location. The size of wire used throughout may be No. 18 annuaciator wire.

Fig. 41.

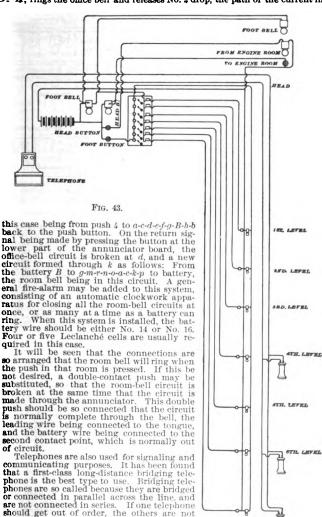
Fig. 42.

A return-call system is illustrated in Fig. 41, in which there is one battery wire b, one return wire r, and one leading wire l_i, l_2 , etc. for each place. The upper portion of the annunciator board is provided with the usual drops, and below these are the return-call pushes. These are double-contact buttons, held normally against the upper contact by a spring. When in this

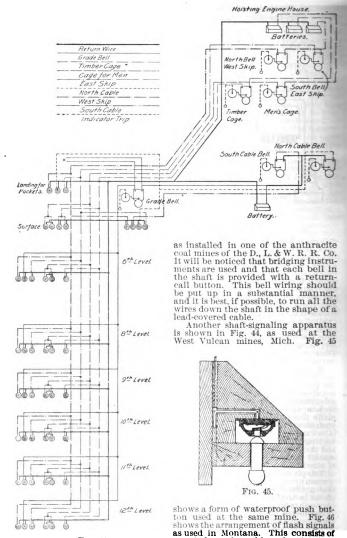
For operating electric bells, any good type of open-circuit battery may be used. The Leclanché cell is largely used for this purpose, also several types of dry cells.

Annuncistor System.—The wiring diagram for a simple annunciator system is

position, the closing of the circuit by the push button in any room, such as No. 4, rings the office bell and releases No. 4 drop, the path of the current in



likely to be disabled. Fig. 43 shows a complete bell annunciator and telephone outfit,



a switch cut into this main circuit at

FIG. 44.

100

300

400

500

Station

Flash

each level of the mines. By pulling out the handle bar of the switch, the lights on this circuit can all be flashed at once, and by a properly arranged code of flash signals, the system can be used for communicating between the surface to any part

of the mine, and between different portions of the mine.

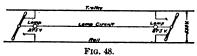
A system of signaling by which signals can be sent to the engine room from any pointalong the

from any pointaining the haulage road is shown in Fig. 47. The conductors a and b, leading from the battery run parallel to each other along the roadside, and about 6 in. apart. A short iron rod, placed across the wires a, b, signals to the engineer, or by simply bringing the two wires

When the engineer hauls from different roads, the signaling system should be supplemented with indicators, so that when the bell rings the indicator would show from which point the signal came, and in case several signals were given at the same time, the engineer should not heed any until the indicator shows that a complete signal came

from one place.

A system of signaling for showing whether or not a section of track is occupied by another motor is shown



e, double-

in Fig. 48. White lights indicate a clear track and darkness an occupied section. A single-center hinge, double-handle switch at each signal station is used and a touch of the handle throws the switch in the desired direction. The

the handle throws the switch in the desired direction. The switches are placed in the roof, 4½ ft. above rails within easy reach of motorman. Fig. 48 shows the connections. Each switch is provided with a spring (not shown in the figure) which, drawing across the center hinge, when the handles are in their central position, insures a perfect contact when the switch is inclined toward either the trolley or rail-terminal plug.

PROSPECTING.

The prospector should have a general knowledge of the mineral-bearing strata, and should know from the nature of the ledges exposed whether to expect to find mineral or not. He should also possess such a knowledge of the use of tools as will enable him to construct simple structures, and a sufficient experience in blacksmithing to enable him to sharpen picks and drills, or

to set a horseshoe, if necessary.

Outfit Necessary.—The character of the prospecting being carried on will have considerable effect on the outfit necessary, which should always be as simple as possible. In general, when operating in a settled country, the outfit is as follows: A compass and clinometer for determining the dip and strike of the various measures encountered; a pick and shovel for excavating, and, where rock is liable to be encountered, a set of drills, hammer, spoon for cleaning the holes, tamping stick, powder and fuse, or dynamite fuse and cap; a blowpipe outfit; a small magnifying glass; an aneroid barometer for determining elevations, and a small hand pick; the latter should weigh about 1‡ lb., and should have a pick on one end and a square-faced hammer on the other, the handle being from 12 to 14 in long.

If the region under consideration has been settled for some time, there will probably be geological, county, railroad, or other maps available.

These may not be accurate as to detail, but will be of great assistance in the work on account of the fact that they give the course of the railroads,

When operating in a mountainous region, away from a settled country, and especially when searching for precious metals, the following materials in addition to that already mentioned, may be required: A donkey or pony packed with a couple of heavy blankets, an A tent, cooking utensils, etc.; a supply of flour, sugar, bacon, salt, baking powder, and coffee, sufficient for at least a month. It is also well to take some fruit, but all fruit containing stones or pits should be avoided, as they are only dead weight, and every pound counts. For the same reason, canned goods should be avoided, on account of the large amount of water they contain. A healthy man will require about 3 lb. of solid food per day. Many prefer to vary the diet by taking rice, corn meal, beans, etc., in place of a portion of the flour.

The additional tools necessary are an ax, a pan for washing gold ore, making concentrating tests, etc., and, in some cases, an assay furnace and outfit packed upon another animal. Where game is abundant, a shotgun or rific will be found useful for supplying fresh meat. In regions abounding in swamps it becomes necessary to operate from canoes, or to take men for porters or packers, who carry the outfit on their backs or heads. These men will carry from 60 to 125 lb.

Plan of Operations.—When the presence of mineral is suspected in a tract of land, a thorough examination of the surface and a study of the exposed rocks, in place, may result in its immediate discovery, or in positive proof of its absence; or it may result in still further increasing the doubt of, or the belief that, it does exist. The first procedure in prospecting a tract of land belief that, it does exist. The first procedure in prospecting a tract of land is to thoroughly traverse it, and note carefully any stains or traces of smut, and all outcrops of every description; and, whenever possible, take the dip and the ocurse of the outcrop with a pocket compass. Any fossils should also be carefully noted, to assist in determining the geological age of the region. These outcrops are frequently more readily found along roads or streams than any other place on the tract. In traveling along the streams, the prospector should pay particular attention to its bed and banks, to see whether there are any small particles of mineral in the bed of the stream, or any stains or smut exposed along the washed banks. If small pieces of mineral are found in the stream a search up it and its tributaries will show mineral are found in the stream, a search up it and its tributaries will show where the outcrop from which the find came is located. When the ravines and valleys are so filled with wash that no exposures are visible, and nothing is gained by a careful examination of them, the prospector must rely on topographical features to guide him.

Any gold present in the vein material usually remains in the float as free or metallic gold, but other valuable metals are often leached out. The fact that the float itself may be barren does not indicate that it may not have come from a very rich deposit, and hence it will often pay to follow barren float, since the outcrop of the vein itself is often either entirely barren, low grade, or of a different nature from the deeper deposits. In cases where there are no outcrops or any other surface indications, it would become

necessary to sink shafts or test pits, or to proceed by drilling.

The absence of any indication of mineral in the soil may not prove that there is not an outcrop near at hand, for the soil is frequently brought from a distance, and bears no relation to the material underlying it. manner, glacial soil often contains débris transported from deposits many miles away; but such occurrences can usually be distinguished by the gen-

eral character of the associated wash material

Frequently, the weathered outcrop of a deposit has been overturned or dragged back upon itself, so as to indicate the presence of a very thick deposit. For this reason, any openings made to determine the character of the material should be continued until the coal or other mineral is of a firm character, and both floor and roof are well exposed. Sometimes, in the case of steeply pitching coal beds, the surface may be overturned for a considerable depth, so that it is difficult to tell which is the roof and which is the floor. Usually, if Stigmariæ are found in the rocks of one wall, it is supposed that this wall is the floor of the seam, while if Sigillariæ, fern leaves, etc. are found in the wall rock, it is probably the roof of the deposit. These indications are not positive proof, for both of these fossils may occur in either the top or bottom wall of a coal deposit, though they are usually found in the positions noted. Coal, clay, gypsum, salt, etc. usually occur in unaltered deposits, i. e., in rocks that have not undergone metamorphism.

The accompanying table gives the names of the various geological periods, both as they occur in America and their foreign equivalents, together with the name of the principal form of life during each period. The various terms employed in geology are defined in the glossary.

2000	ERIODS	in the			2.16.		
45	£	Eras		American Periods	Foreign Equivalent	,	
	TOCENE	Quaternory		Recent Champlain	Recent	Age of Man	
Cenozorc	MEISTON	Quart	50,000	Glacial	Pleistocene	Age of Man Age of Mammais Age of Reptites Age of Amphibians or Age of Amphibians or Age of Arrogens (plants of the coolpariod) Age of Fishes	
	SINE	GITTAL GITTAL		Pliocene	Pliocene	Ageof	
	COCENE NEOCENE	Tertion		Miocene	Miocene	Mammals	
	EDCEN	Ter		Eocene	Eocene		
	CRETACEOUS	Cretaceous	\$P\$P\$9\$P\$	(Laramie Series) Upper Cretaceous	Upper Cretaceous		
	CRETA	Oreto	DAME OF THE STATE	Lower Cretaceous (Dakota Group) (Comanche Group)	Lower Cretaceous or Neocomian	Age of	
0	-	·u	TOUR SERVICE	(Communité Croup) Neocoman Age of Alantosouris Ostité Reptiles. Bads Los Reptiles. Connecticut River Associatai Bada Muschalitai Bads Bunter Sandstein Bunter Sandstein	300		
Mesozio	TRIAS	Junassic				Reptiles	
	JURATRIAS	Triassic			Muschalkalk		
3	-	K					
ì	US			Permian	Permian		
	FERO	erous		Carbonterous	Carboniferous	or	
W	CARBONIFEROUS	Carboni ferous	warsilinia k	Coal Measures.	Coal Measures	Acrogens	
	CAR	8		Subcarboniferous	Mountain Limestone		
	DEVONIAN			Catskill. Chemung.		Age of	
,,,		Devonian		Hamilton	Old Red Sandstone		
Paleozoic	DEV	08		Corniferous		Fishes	
Pa			Oriskany				
		ian		Helderberg Onondaga. Salina	Ludlow		
	PIAN	Silur	Nogara W	Wenlock Liandovery			
	SILURIAN	Lower	क्षानुस्तिहरू इ.स.च्या	Trenton	Bala or Caradoc Llandeilo Flags		
		5/16	14 7 7 7 7 7	Canadian	Arenig	Age of	
	MANBRIAN	Tornan	The state of the s	Potsdam Acadian	Tremadoc Slates Lingula Flags Manevian Solva	Inversebrate.	
	SAM	Camp	2.252 2.22	Georgian	Caerfai		
		Migon (Huronian			
Fozoic		rehean		Lourentian	Archean	Remains	
E		Are	Section 2			No Organio Remains	

Metals and metallic ores usually occur in rocks that have undergone more or less metamorphism. This change may have been accompanied by heat and volcanic disturbances sufficient to render the rocks thoroughly crystalline, or it may simply have been the converting of limestone into dolomite.

The prospector for metals usually avoids regions in which the rocks have been wholly unaltered; while, on the other hand, a region covered by extensive flows of basalt is generally barren. As the vein filling of most metal-bearing deposits has been deposited from circulating water, it stands to reason that porous rock formations are more favorable to the occurrence of metallic ores than are hard, dense, rock formations. As a rule, ore deposits are more common at the junction of two dissimilar rock formations, as, for instance, the contact between limestone and porphyry.

When a prospector is operating in any particular region, it is best to study carefully the conditions of that region before proceeding, as such factors as lack of rain, frozen ground, etc. may have played an important part in determining the character of placer or fragmentary deposits, and the outcrop and surface appearance of other deposits. Experience obtained

in one region is frequently very misleading when applied in another.

Cosl or Bedded Materials.—The presence of the outcrop of any bed may often be located by a terrace caused by the difference in the hardness of the strata; but as any soft material overlaying a hard material will form a terrace, it is necessary to have some means of distinguishing a coal or ore terrace from one caused by worthless material. Usually, the outcrop of a coal terrace will be accompanied by springs carrying a greater or less amount of iron in solution, which is deposited as othery films upon the stones and or iron in solution, which is deposited as ochery nims upon the stones and vegetable matter over which the water flows. The outcrops of beds of iron or other ores are very frequently marked by mineral springs. Sometimes the outcrop of a bed will be characterized by a marked difference in the vegetation, as, for instance, the outcrop of a bed of phosphate rock by a luxuriant line of vegetation, the outcrop of a mineral bed by a lack of vegetation, the outcrop of a coal bed contained between very hard rocks by more luxuriant vegetation than the surrounding country, etc. Some indication as to the dip and strike of the material composing the bed may be obtained by experience from a be obtained by examining the terrace and noting the deflections from a straight line caused by the changes in contour of the ground. If the variathe caused by a depression is toward the foot of the hill, the bed dips in the same direction with the slope of the ground; but if the deflection is toward the top of the hill, the dip is the reverse from the slope of the ground, or into the hill. After any terrace or indication of the outcrop of a bed has been discovered, it will be necessary to examine the outcrop by the control of the first transfer. means of shafts, tunnels, or trenches. The position of such openings will depend on the general character of the terrace. If the dip appears to be with the hill, a trench should be started below the terrace and continued to and across it; while if the dip appears to be into the hill, it may be best to sink a shallow shaft above the terrace.

Formations likely to Contain Coal.—No coal beds of importance have as yet been found below the Carboniferous period, but coal may be looked for in any stratified or sedimentary rocks that were formed after this period, although the bulk of the best coal has, up to the present time, been found in the Carboniferous period. As a rule, highly metamorphic regions contain no coal, and the same may be said of regions composed of volcanic or igneous rocks. An examination of the fossils contained in the rocks of any locality will usually determine whether they belong to a period below or above the Carboniferous, and hence whether there is a probability of the formations containing coal. On account of this fact, the prospector should familiarize himself with the geological periods, and, by referring to any elementary geology, with the most common fossils of the various periods. The rocks most common in coal measures are sandstones, limestones, shale, conglomerates, fireclays, and, in some localities, the coal deposits are frequently associated with beds of iron ore.

Ore deposits, as is well known, are generally found in mountainous districts, rather than in the undisturbed horizontal strata of the plains and mountain parks—usually deep in the core and center of the mountain system, rather than along their flanking foot-hills. Consequently, not only are the prairies and flat portions of the mountain parks to be avoided, but also the zone of uptilted strata on the edges of prairies and parks, commonly called hogbacks. These hogbacks are the natural "habitat" of such

conomic products as coal, petroleum, building stone, clays, etc., but not often if the precious metals. The reason for this appears to be that the latter are ommonly found to be associated with evidences of more or less heat. he Rocky Mountains they are rarely found except where volcanic eruptions have at some time been active, or where the strata have been changed or netamorphosed and crystallized by heat.

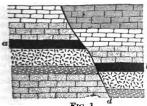
As metallic ore bodies occupy fissures and other openings in the earth's crust, we must go to regions where the greatest disturbances and uplifts have occurred, accompanied by the greatest rending and contortions of the

rocks, and eruptions of volcanic matter.

As a broad assertion, we may say that the greater part of any mountain region is a prospecting field, with the exception of those areas we have restricted as unpromising. But over this wide area of more or less metamorphosed and crystalline rocks, there are regions and localities where the precious metals have already been found, and others where on geological grounds they are most likely yet to be found, and those are generally where eruptive forces have been especially active, where once molten eruptive rocks are most abundant, and the disturbance and crystallizing of the strata most pronounced.

Position of Veins and Ore Deposits.—Ores, as a rule, are to be looked for at the junction of any two dissimilar rocks, rather than in the mass of those rocks. However, there are many exceptions to this, where the mass of a decomposed dike or sheet of porphyry has been impregnated by free gold or gold-bearing pyrites, and the whole rock is practically a gold vein. mass, the richest gold is often found in a network of little quartz veins running through the porphyry mass. Some of our richest gold mines are found

in "rotten,



decomposed, oxidized dikes and sheets of porphyry; but this is rarely the case with lead-silver ores, which frequent rather the lines of contact in limestones or in fissure veins in granite. The Cambrian quartzites a few years ago were rather avoided by the prospectors, their extreme hardness presenting great difficulties in mining, and from the fact that they were generally supposed to be barren. The late discovsupposed to be barren. The late discoveries of very rich gold deposits in them. and of similar deposits in quartzites of a later age, have drawn more attention to them. The gold has been found in a free state associated with oxide of iron in cavernous deposits, and in close proximity to eruptive rocks. In the granitic

rocks, both gold and silver occur in fissure veins associated with pyrites, galena, etc. These fissures, occupied by mineralized quartz veins, may occur galena, etc. These fissures, occupied by mineralized quartz veins, may occur in the granite or gneiss alone, or be at the contact of these rocks with a

porphyry dike.

Veins in overflows of volcanic lava generally fill a fissure having a more or less steep inclination, penetrating the lava sheets, caused probably by shrinkage of the molten lava on cooling. These fissures, in some case say likely to be limited in depth to the thickness of the lava sheet. Where, in a few rare cases, the fissure has been traced down to the underlying granite or

some other rock, it has come abruptly to an end.

Underground Prospecting.—Frequently a seam or deposit becomes faulted or pinched out underground, and it is necessary to continue the search by means of underground prospecting. Underground prospecting is, to a large extent, similar to surface prospecting, the underground exposures being simply additional faces for the guidance of the engineer. In the case of coal beds or similar seams, if a fault or dislocation is encountered, the manner of carrying on the search will depend on the character of the fault. Where sand faults or washouts are encountered, the drift or entry should be driven forwards at the angle of the seam until the continuation of the formation is encountered, when a little examination of the rocks will indicate whether they are the underlying or overlying measures. In the case In the case of dislocations or throws, the continuation of the vein may be looked for by Schmidt's law of faults, which is as follows: Always follow the direction of the greatest angle. It has been discovered by observation that, in the majority of cases, the hanging-wall portion of the fault has moved down, and on this account such faults are commonly called normal faults. For instance, if the bed a b, Fig. 1, were being worked from a toward the fault, upon encountering the fault, work would be continued down on the farther side of the fault toward d, until the continuation of the bed toward b was encountered. In like manner, had the work been proceeding from b, the exploration would have been carried up in the direction of the greatest angle, and the continuation toward a thus discovered. A reverse fault is one in which the movement has been in the opposite direction to a normal fault. cially in the case of precious metal mines, where the material occurs as perpendicular or steeply pitching veins, faults are liable to displace the deposit, both horizontally and vertically, in which case it may be difficult to determine the direction of the continuation of the ore body; but frequently pieces of ore are dragged into the fault, and these serve as a guide to the miner, and indicate the proper direction for exploration. Where a bed or seam is faulted, its continuation can frequently be found by breaking through into the measures beyond, when an examination of the formation will indicate whether the rocks are those that usually occur above or below the desired seam.

Prospecting for Placer Deposits.—Placers are fragmental deposits from water in which the heavier minerals have been concentrated in certain portions usually next the underlying, or bed, rock. The materials that are recovered from placer deposits are metallic gold, tinstone, monazite, sand, or precious stones. Placer deposits are modern or ancient. Modern placers are deposits of washed material, or débris, in the beds or along the banks of streams that are either now in existence or existed in comparatively recent Placer deposits may also occur in deposits along the seashore. Ancient placers are fragmental accumulations, similar to the modern placers, which have been buried under accumulations of strata or flows of

lava, and they may or may not have become consolidated into rock.

At times, placers are very compact, owing to the presence of large quantities of oxide of iron or calcium carbonate, or similar cementing material. Often, in the case of modern placers, the streams, or other sources of water that deposited the material, have changed their course so that the placer deposit is now high up in the benches bordering the streams, or, possibly, even on the top of the present hills. Such deposits are commonly called bench deposits, while those along the sides of the streams below the high-

water mark are called bar deposits, diggings, or placers.

Frequently, a large portion of the gold or other valuable material is found in pockets or irregularities in the bed rock, but the pot holes under waterfalls are frequently barren of gold, on account of the fact that the current there was sufficiently swift to wash everything out, either heavy or light. When the soil is saturated with water, the mass may partake of the nature of a semifluid through which the heavy particles of gold settle until they accumulate on the bed rock.

When prospecting for placers, the miner examines the country for any indications of present or ancient watercourses in which the deposits of placer material have been formed. He pans the dirt from any deposits discovered, to see if it contains colors (small particles of metallic gold). If colors are found, more extensive operations are in order, and hence he sinks to bed rock and examines the material thoroughly, to see if it contains

a paying quantity of the valuable mineral.

The form of placer deposit in dry or arid regions differs from that in regions where the rivers have a continuous flow, on account of the fact that the deposits are largely the result of sudden rushes of water partaking of the nature of cloudbursts, hence the rich portions in the placer material are very irregular, and are rarely situated on bed rock, but are usually found on any strata that formed the bottom of the ravine during the sudden rush of water. During the rainy season in arid regions, the surface soil is some-times softened for a few inches, so that it becomes practically a mud, and particles of gold that it may contain tend to settle to the bottom of the soft portion, thus rendering the surface barren. This barren surface may be subsequently washed away by the rain, or blown away as dust during the dry season. The repeating of this process year after year results in the removal of considerable of the original surface and the formation of a rich stratum just below the grass roots. Prospectors in arid regions, who have been used to operating in an ordinarily well-watered country, are frequently deceived by finding this rich ground so high up in the deposit, not knowing that it is no indication as to the value of the material at a greater depth.

In many cases, in the arid regions the portion of the deposit upon bed rock is entirely barren. In like manner, frozen ground may play an important part in the formation and distribution of the values in placer deposits.

Gems and precious stones are prospected for in a manner similar to that employed in searching for placer material, and are usually found in alluvial deposits, from which they are obtained by washing. In a few cases, gems are found in the rocks themselves; as, for instance, diamonds in the hard matrix that occurs as pipes or chimneys in metamorphic rocks, and which, upon exposure to the atmosphere, becomes decomposed, so that the stones are easily removed. Some of the corundum minerals are found in lime-stone and metamorphic or crystalline rocks. Turquoise usually occurs in veins, the outcrop of which is stained with carbonate of copper. In most cases, it does not pay to extract gems from rock formations when the rock is extremely hard, owing to the fact that the gems are liable to become broken

in separating them from the rock matrix.

For gem prospecting, the following outfit has been recommended: A shovel and pick; two sieves, one of 2 or 3 meshes to the linear inch, and the other of 20 or more meshes to the inch (the coarse sieve should be arranged to fasten on top of the finer one for use together); a tub in which the sieves can be submerged in water; an oilcloth on which to sort the gravel; several stones and crude gems as a scale of hardness; a small pocket magnifying glass, and a dichroscope. In some cases, a portion of the outfit is dispensed with. The use of the outfit may be explained as follows: The tubic partially with. The use of the outfit may be explained as follows: The tub is partially filled with water, the two sieves fastened together, and a shovelful of material placed in the upper one, when they are submerged in water, the large stones cleaned and examined, and all of the fine material worked and examined, and an of the fine material worked through the upper sieve, which is then removed, the material on it examined and disposed of. The material in the fine sieve is then washed until free from clay, when a little jigging motion in the water will carry the lighter material to the top. The sieve is then quickly inverted and the material dumped out on the olicloth, thus bringing the heavier stones to be the state of the provided with the state of t the top. The various pieces should now be examined with the magnifying glass, scale of hardness, etc., and the identity of any doubtful colored gems settled, by means of the dichroscope. Few precious stones are of sufficient specific gravity to be concentrated in distinct beds, like gold or tinstone, but they are usually fairly well concentrated and freed from much of the lighter worthless material.

Value of Free Gold per Ton of Ore.—The accompanying table was prepared by Mellville Atwood, F. G. S., and its use may be explained as follows: If a 4-lb. sample of quartz be crushed, the gold separated by panning and

VALUE OF FREE GOLD PER TON OF ORE. (Risdon Iron Works.)

Weight, Washed Gold. 4-Lb. Sample. Grains.	Fineness, 780. Value per Oz., \$16.12.	Fineness, 830. Value per Oz., \$17.15.	Fineness, 875. Value per Oz., \$18.08.	Fineness, 920. Value per Oz., \$19.01.
Giamp.	V 10.12.	417.10.	41 0.00.	Q15.01.
5.0	\$83.97	\$ 89.36	\$94.20	\$99.05
4.0	67.18	71.49	75.36	79.24
3.0	50.38	53.61	56.52	59.43
2.0	33.59	35.74	37.68	39.62
1.0	16.79	17.87	18.84	19.81
	15.11	16.08	16.95	17.82
.8	13.43	14.29	15.07	15.84
.7	11.75	12.51	13.19	13.86
.6	10.07	10.73	11.30	11.88
.5	8.40	8.93	9.42	9.90
.4	6.71	7.14	7.53	7.92
.3	5.03	5.36	5.65	5.94
.9 .8 .7 .6 .5 .4 .3	3.36	3.57	3.76	3.96
.1	1.68	1.78	1.88	1.98

amalgamation, the quicksilver volatilized by blowpiping or otherwise, and the resulting button weighed, the value of the ore per ton of 2,000 lb. will be found opposite the weight of the button. The values are given for fine-

ness of gold varying from 780 to 920.

To determine the value of gravel, a 6-lb. sample will give the same results as that obtained from a 4-lb. sample of quartz, on account of the fact that 18 cu. ft. of gravel measured in a bank weigh 1 ton, or 2,000 lb.; hence, a cubic yard of gravel measured in a bank weighs 3,000 lb., and for this reason a sample one and one-half times as large as that required for quartz must be taken. In case the gravel is of low grade, a sample ten times as large, or 60 lb., may be taken, in which case the value opposite the weight of the button will have to be divided by 10.

As an example, in the use of the table we may suppose that a button from 4 lb. of ore or 6 lb. of gravel weighs 3.8 gr., and that the fineness of the gold is 830. Opposite 3 in the table we will find \$53.61 as the value of the button in dollars containing 3 gr., of gold, and opposite .8 we will find \$14.29. The sum of these is \$67.90, the value of the ore per ton, or the gravel

per cubic yard.

EXPLORATION BY DRILLING OR BORE HOLES.

Earth Augers.—When testing soil or searching for placer gold, sand, soft iron, or manganese ores, and similar materials that usually occur comparatively near the surface, hand augers may be employed to great advantage. A good form of hand auger consists of a piece of flat steel or iron, with a A good form of hand auger consists of a piece of hat seel of fron, with a steel tip, twisted into a spiral about 1 ft. long, and having four turns. The point is split and the tips sharpened and turned in opposite directions and dressed to a standard width, usually 2 in. The auger is attached to a short piece of 1" pipe, and is operated by joints of 1" pipe, which are coupled together with common pipe couplings. The auger is turned by means of a devided headly beginned to the coupled together with common pipe couplings. double-ended handle having an eye in the center through which the rod Dasses.

The handle is secured by means of a setscrew. In addition to the auger, it is well to have a straight-edged chopping bit for use in comparatively hard seams. This may be made from a piece of 1?" octagon steel, with a 2" cutting edge. The upper end of the steel is welded on to a piece of pipe similar to that carrying the auger. When the chopping bit is employed, it is necessary to have a heavy sinking bar, which may be made from a piece of solid 1½" iron bar, fitted with ordinary 1" pipe threads on the ends. Prospecting can be carried on to a depth of from 50 to 60 ft. with this outfit. The number of men necessary to operate the rods varies from 2 to 4, depending on the depth of the hole being drilled. When more than 30 ft. of rods are in use, it is usually necessary to have a scaffold on which some of the men can stand to assist in withdrawing the rods. When withdrawing the rods, to remove the dirt, they are not uncoupled unless over 40 ft. of rods are in use at one time, and sometimes as many as 50 or 60 ft. are drawn without uncoupling.

Percussion or churn drills are frequently employed in drilling for oil, water, or gas, and were formerly much used in searching for coal and ores, but, owing to the fact that they all reduce the material passed through to small pieces or mud, and so do not produce a fair sample, and to the fact that they can only drill perpendicular holes, they are at present little used

in prospecting for either ore or coal.

COST OF WELL-DRILLING.

Size of Well. Inches.	Cost per Foot.
6	\$1.50
8	2.25
10	3.00
12	5.00
15	8.00

The cost and rate of drilling by means of a percussive or churn drill varies greatly, being affected much more by the character of the strata penetrated than is the case with the diamond drill. In the case of highly inclined beds of varying hardness, the holes frequently run out of line and become so crooked that the tools wedge, and drilling has to be suspended. For drilling through moderately hard formations, usually encountered in searching for gas or water, such as sandstones, limestones, slates, etc., the accompanying costs, from the American Well Works, Aurora, Ill., may be taken per foot for wells from 500 to 3,000 ft. deep for the central or eastern portion of the United

States at present (1900). This cost includes the placing of the casing, but not the casing itself.

When drilling wells for oil or gas to a depth of approximately 1,000 ft., using the ordinary American rig with a cable, the cost is sometimes reduced to as little as 65 cents per foot for 6" or 8" wells. This is when operating in mather soft and known formations. From 15 to 40 ft. per day of 24 hours is usually considered a good rate of drilling, though in soft materials as much as 100 ft. may be drilled in a single day, and at other times, when very hard rock is encountered, it is impossible to make more than from 1 to 2 ft. per

day.

The diamond drill is the only form that has been universally successful in the diamond drill is the only form that has been universally successful in the diamond drill. Even in drilling in any direction through hard, soft, or variable material. the use of the diamond drill, many difficulties present themselves, and demand careful study in adapting the form of apparatus to the work in hand, and in rightly interpreting the results obtained from any set of

observations.

NOTE.—See "Mines and Minerals" for articles on Diamond-Drilling

Practice, by H. M. Lane, August, 1899, to January, 1900, Vol. XX.

Selecting the Machine.—It is not economy to employ a machine of large capacity in shallow explorations, as the large machines are provided with powerful motors, and hence do not work economically under light loads. When a large machine is operating small rods on light work, the driller cannot tell the condition of the bit, or properly regulate the feed. The machine should possess a motor of sufficient capacity to carry the work to the required depth, but where much drilling is to be done, it is usually best to have two or more machines, and to employ the small ones for shallow

holes, and the large ones for deep holes.

All feed mechanisms employed in diamond drilling may be divided into two classes: (1) Those that are an inverse function of the hardness of the material. This class includes friction, spring, and hydraulic feeds. (2) Those in which the feed is independent of the material being cut, as in the case of

the positive gear-feed.

The first class is advantageous when drilling through variable measures in search of fairly firm material, which does not occur in very thin beds or seams. On account of the fact that this class of feed insures the maximum amount of advance of which the bit is capable in the material being cut, the danger is that the core from any thin soft seam may be ground up and washed away, without any indication of its presence having been given.

The second class, or positive gear-feed, if properly operated, requires somewhat greater skill, but if used in connection with a thrust register, it

gives reliable information as to the material being cut, and is especially

useful when prospecting for soft deposits of very valuable material.

Size of Tools.—The size of tools and rods, and consequently the size of the core extracted, depends on the depth of the hole and the character of the material being prospected. When operating in firm measures, such as anthracite coal, hard rock, etc., it is best to employ a rather small bit, even when drilling up to 700 ft., or more, in depth. For such work, a core of from in to 1A in is usually extracted. The rate of drilling with a small outfit is very much greater than with a large one, owing to the fact that there is a small cutting surface exposed, and the rate of rotation of the rods can be much greater. When prospecting for soft materials, such as bituminous coal, valuable soft ores, or for disseminated ores, such as lead, copper, gold, sliver, etc., it is best to employ a larger outfit and extract a core 2 or 3 in. in diameter, and sometimes even larger, even though a comparatively small machine is used to operate the rods.

Drift of dismond-drill holes, or the divergence from the straight line, often comes a serious matter. This trouble may be minimized by keeping the becomes a serious matter. tools about the bit as nearly up to gauge as possible. Core barrels, with spiral water grooves about them, answer this purpose very well if they are

renewed before excessive wear has taken place.

Surveying of diamond drill-holes may be carried on by either one of two methods, depending on the magnetic conditions of the district. Where there is no magnetic disturbance, the system developed by Mr. MacGeorge, of Australia, may be employed. This consists in introducing into the hole, at various points, small tubes containing melted gelatine, in which are suspended magnetic needles and small plummets. gelatine has hardened the tubes are removed, and the angles between the center line of the tube, the plummet, and the needle noted, thus furnishing the data from which the course of the hole can be plotted. This method gives both the vertical and the horizontal drift.

Where there is magnetic disturbances the needle cannot be used, but a system brought out by Mr. G. Nolten, of Germany, has been quite extensively employed. In this case, tubes partly filled with hydrofluoric acid are sively employed. In this case, tubes partly filled with hydronuoric acid are introduced into the hole, at various points, and the acid allowed to etch a ring on the inside of the tube. After the acid has spent itself the tubes are withdrawn, and by bringing the liquid into such a position that it corresponds with the ring etched on the inside of the tube, the angle of the hole at the point examined can be determined. This method gives a record of the vertical drift of the hole only.

The value of the record furnished by the diamond drill depends largely on the character of the material sought. The core extracted is always of very small volume when compared with the large mass of the formation pros-pected, and hence will give a fair average sample only in the case of very uniform deposits. The value of the diamond drill for prospecting may be stated as follows: More dependence can be placed on the record furnished by the diamond drill when prospecting for materials that occur in large bodies of uniform composition than when prospecting for materials that occur in small bunches or irregular seams. To the first class belong coal, iron ore, low-grade finely disseminated gold and silver ores, many deposits of copper, lead, zinc, etc., as well as salt, gypsum, building stone, etc. To the latter class belong small but rich bunches of gold, silver mineral, or rich streaks of gold telluride.

The arrangement of holes has considerable effect upon the results fur-If the material sought lies in beds or seams (as coal), the dip of which is fairly well known, it is best to drill a series of holes at right angles to the formation. If the material sought occurs in irregular bunches, pockets, or lenses, it will be necessary to drill holes at two or more angles, so as to divide the ground into a series of rectangles, thus rendering it practically impossible for any vein or seam of commercial importance to exist without being discovered. Where the surface of the ground is covered with drift and wash material, it may be best to sink a shaft or drill pit to bed drift and wash material, it may be best to sink a shart of drill pit to been rock, and locate the machine on bed rock. After this, several series of fan holes may be drilled at various angles from the bottom of the pit. Owing to the upward drift of diamond-drill holes, the results furnished from a set of fan holes drilled from a single position would make a flat bed appear as an inverted bowl, or the top of a hill. On this account, it is best to drill sets of fan holes from two or more locations, so that they will correct one another. If fan holes from different positions intersect the same bed, a careful examination of them will usually furnish a check on the vertical drift of the holes of the holes.

The cost and speed of drilling depend greatly on the formation being penetrated. As a rule, it is more expensive to sink the stand pipe than to do the subsequent drilling. Stand pipes may cost \$5 or more per foot to sink, while the cost of drilling in firm rock varies from \$0.50 to \$2 per foot; in the case of difficult drilling, the cost may run over \$4 per foot. Where a large amount of drilling has to be done, a fair average estimate for shallow holes up to 700 ft. deep would be \$2 per foot, under such conditions as exist in most mineral districts of the United States. The cost of labor, fuel, etc., enter into the problem, and frequently affect it to a considerable extent.

The rate of drilling varies considerably, but in firm rock an average of 1 ft. per hour, including all delays for changing rods, etc., would be a fair average up to 700 ft. Greater speed than this could be made in soft shales or sandstones, and somewhat less in hard rock. The hardness of the rock affects the rate of drilling much less than does its character. A conglomerate rock containing loose pebbles that come out during the drilling, or a crystalline rock containing angular pieces that come out during drilling, will cause far greater trouble than the hardest material ever encountered in diamond drilling. The following tables will give some idea as to the cost

of diamond drilling under various conditions.

The cost of drilling 2,084 ft. of hole in prospecting the ground through which the Croton aqueduct tunnel was to pass is given as follows:

814 ft. of soft rock (decomposed gneiss), in which an average of 23.1 ft. per

day was drilled, at a cost of \$1.15 per ft.

347 ft. of hard rock (gneiss), in which an average of 11.1 ft. per day was

drilled, at a cost of \$3.97 per ft.

23 ft. of clay, gravel, and boulders, in which from 64 to 9 ft. per day were drilled, at a cost of \$4.07 per ft.

The average progress per day in drilling the entire 2,084 ft. was 10.2 ft per day.

Per Ft.

80.237

0.017

0.045

0.083

0.502

\$0.884

Amount.

134.13

360.73

663.36

4.000.03

In the Minnesota Iron Co.'s mines, at Soudan, Minn., the diamond drill is used for drilling holes from 10 to 40 ft. in depth in the back of the stopes, practically all the work being done in iron ore. The average cost per foot of drilling 13,512 ft. of hole was \$0.7703, which was divided as follows:

Carbons		2 0.34
Supplies.	oil, etc.	0.07
Fuel	·	0.04
Repairs		0.05
Total	***************************************	\$0.7703

The following tables give the cost of boring at two Ishpeming, Mich., mines:

TABLE I.

	Total	Cost
(400 ¹ days setter at \$3.00 \$1,200.75)	Cost.	per Ft.
Labor 372 days runner at 2.25 837.00	\$2,506.10	\$0.669
Labor	42,000.10	40.003
41 days laborer at 1.75 7.85		
Carbon 68† carats at \$15.144	. 1,035.47	0.276
Bits, lifters, shells, barrels, and repairs		$0.115 \\ 0.035$
Oil, candles, waste, and supplies Estimated cost compressed air	. 125.09	0.035
Total		
		Ф1.195
Number holes drilled		28
Drilled in hematite		193 ft.
Drilled in jasper		646 ft.
Drilled in mixed ore		986 ft.
Drilled in dioritic schist	••••	1,921 ft.
Total drilling		3,746 ft.
Number of 10-hour shifts drill was running, i moving and setting up		603 6.2 ft.
TABLE II.		
Underground drilling		6,075 ft.
Surface drilling Stand pipe sunk		1,414 ft.
Total distance run		7,959 ft.
Actual drilling time underground	6	72 shifts
Actual drilling time on surface	10	65 shifts
Time of foreman, setter, moving, and stand-pipir	ng 1,3	14 shifts
Total time worked	2.1	51 shifts
	-,-	
Average progress per man per shift	3.70	ft.
Average progress per drill per shift actually i	run-	
ning	8.95	ft.
Weight of carbon consumed	111.00	carats
Distance drilled per carat of carbon consumed	67.38	5 IL.

Cost of supplies and oils.....

Cost of fuel

Cost of shop material, etc.....

RECORDS OF COST PER FOOT IN DIAMOND DRILLING.

	A	В	C	D	B	F	G	H	I	J	K	L	M	N	0
		— <u>-</u> -!		;	!	I	<u>'</u> '								
Labor	.707	1.040	2.483	1.150	.581	1,615	1.030	1.720	1.189	1.284	.721	1.200	.939		
Fuel	.094	.270	.256	.019	.000	.216	,090	.214	.157	.339	.419	.329	.126	.182	
Camp account	.373	.559	.789	.538			.384	.549	.516	.495	.519	.595	.644	.722	.630
Repairs	.139	.110	.294	.171	.135	.144	.103	.185	.154	.165	.040	.087	.138	.126	.116
Supplies	.034	.065	.039	.074	.023	.032	.011	.039	.048	.097	.020	.092	.076	.097	.086
Carbon	.263			.860	.843	1.587	.934	.684	.684	.733	.227	,209	.553	.239	.330
Supt	.239								.259	.172		.220	.106	.196	.195
					ı——'	[']								!	
Total	1.849	3.024	5.348	2.852	1.940	4,407	2.692	3.696	3.007	3.285	2.293	2.732	2.582	2.374	2.604

- A 5 holes, 1,066 ft.
- Sandstone and marble.
- B 1 hole, 1,293 ft. Black slate and jasper.
- C 3 holes, 478 ft.
- Jasper, very hard. D 5 holes, 780 ft.
- Jasper, hard. E 1 hole, 216 ft.
- Iron slates.
- F 1 hole, 174 ft.
 Jasper and slate.
- G 2 holes, 267 ft. Jasper and s'ate.
- H 3 holes, 410 ft. Jasper.

- I Average cost of total work of drilling 21 holes. Total of 4,684 ft.
- J 2 holes, 634 ft. Iron slates.
- K 2 holes, 360 ft. Schist and jasper.
- L 6 holes, 1,350 ft.
- Iron slates.

 M 2 holes, 611 ft.
- Schist, jasper, and quartzite.
- N 6 holes, 2,091 ft. Quartzite.
- O Average cost of drilling 18 holes, 5,046 ft.

The following figures, taken from a letter written by T. F. Richardson, Departmental Engineer of Dam and Aqueduct Department, Metropolitan Water Board of Boston, and published by the U. S. Geological Survey, are of interest, as they show the rate and cost of diamond drilling under certain conditions. The costs do not take into account depreciation of machinery nor losses of time in moving machines, etc. The machines employed in this work were a Badger drill, manufactured by the M. C. Bullock Manufacturing Co., of Chicago, Ill., and an S-510 drill, manufactured by the Sullivan Machinery Co., Claremont, N. H.

The total amount drilled was 2.814 ft., the deepest hole being 280 ft. deep, and the converse durbage hole shoule \$0.00.

The total amount drilled was 2.814 ft., the deepest hole being 286 ft. deep, and the average depths of holes about 60 ft. The amount accomplished per day was from 0 to 32 ft., the average amount being probably about 10 or 12 ft. per day. The cost of drilling varied very largely, both with the hard-

ness of the rock and the condition of the rock as to being seamy.

The following was the cost of drilling 324.2 ft. of rather hard, tough diorite rock:

Labor	\$ 341.25
Diamonds	
Coal	17.50
Total	\$433.05
Cost per foot	

. (86.6 ft. of this was drilled with a 14" bit, and 237.6 ft. was drilled with a 14" bit.)

Drilling 150.7 ft. of very hard syenite rock:

Labor	\$158.00
Diamonds	298.69
Coal	10.50
Total	\$467.19
Cost per foot	3.10
(Size of drill, 17 in.)	

The following was the	cost of drilling 286.1 ft. of soft schist	rock:
Labor		\$190.00
Diamonds		87.75
Coal		11.50
Total		\$289.25
Cost per foot		1.01
(Size of drill, 13 in	.)	

The following figures will be of considerable interest, owing to the fact that the work is practically all of the nature of sinking stand pipes, the object of the exploration being to ascertain the depth of wash material and the character of the bed rock over the area of certain proposed dam sites in the southwestern portion of the United States, the work being carried on by the government. The machines used were made by the American Diamond Rock Drill Co., of New York, and had previously been employed in similar exploration along the line of the Nicaragua Canal.

Cost of operation per month of bed-rock explor Foreman	\$150.00 234.00	\$ 429.00
240 rations, at 60 cents	500.00	144.00
Total moving	670.00 200.00	
Total, 10 months Sundry expenses per month		_230.00
Total cost per month 10 months, at \$803		803.00 8,030.00
Total number of feet sunk		3,254.20 \$8,030.00 2.46 154.42

The drills were purchased second-hand from the Nicaragua Canal Co., and the other apparatus was new. If the original cost of all this machinery were distributed over the work, the results would be as follows:

Operation	\$8.030.00
Operation	1,600.00
Total cost	
Or average cost per foot	

Both machines are still in good repair, after having been used in Nicaragua and in various localities in Arizona and California.

The total depths penetrated in all materials at the various dam sites are as follows:

	Covering.	Rock.	Total.
The Buttes	1.621.2	196.0	1,817.2
Queen Creek	357.8	55.6	413.4
Riverside	729.8	40.2	770.0
Dikes	80.0	0.0	80.0
San Carlos	143.2	30.4	173.6
Total	2,932.0	322.2	3,254.2

Magnetic Prospecting.—Bodies of magnetic iron ore are frequently discovered or located on account of their magnetic properties. Two forms of compasses are employed in this work: the dipping needle, or miners compass, and the ordinary compass. The ordinary compass is used to find the center of magnetic attraction in the horizontal plane, and after this has miners'



been found the ground may be run over with the been found the ground may be run over with the dipping needle, to locate the center of attraction by this means. The ordinary compass does not give good results when operating over a magnetic deposit, but is only useful in determining its outside edge, and thus locating its general position. The dipping needle differs from the ordinary compass in that the needle is hung in a vertical plane in place of horizontally, so that from the horizontal, depending on the downward component of magnetic attraction at that point. The vertical magnetic component at the point.

attraction at that point. The vertical magnetic component at the point should be compensated for by balancing the dipping needle so that it will ordinarily stand horizontally when not affected by local disturbances.

The actual work of prospecting may be carried on as follows: If there were an outcrop of a vein of magnetic material, as shown in Fig. 2, covered with a capping of wash material, the preliminary prospecting would be carried on as shown in Fig. 3, the dipping needle being carried backwards and forwards zigzag across the deposit, noting the point of maximum dip in

each case and establishing a stake there as indicated by the crosses. After these stakes had all been established, an average straight line would be struck through them that would follow the course of the deposit as nearly as possible. Stakes would be placed at the ends of this line, as at X and Y, and the line XY divided off into 100' distances by means of stakes marked A, B, etc. Lines at right angles to the original line would then be turned off at these 100' points, and stakes placed every 10 ft. upon the branch lines. These points on the branch lines would be lettered with small letters, corresponding to the large letter on the line X Y, as shown in Fig. 4, which represents the observations taken at the first station. The dip would be noted at each one of the 10' stations, and recorded in the note book. A convenient method of keeping the notes is to have a vertical line down the center of the page for the line XY, and other vertical lines to the right and left of it for the individual stations 10 ft. apart, each side of the main

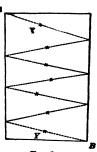


FIG. 3.

line, the horizontal lines across the page being lettered A, B, etc., the stations to the right and left being marked with primes and subscripts of the small letters corresponding to the line. After the observations have been taken, lines may be drawn through points of equal dip and equal deflection

(isogonic lines). Bythis means the general form of the bed is determined.

10

FIG. 4.

The maximum dip, in the case of an inclined deposit like that shown in Fig. 2, would occur at c, over the hanging wall of the outcrop, the dip at b being considerably less, and the dip at a being less than that at b. After the center of magnetic attraction has been discov-

ered, prospecting may be continued by means of the diamond drill, or by sinking shafts or test pits. Sometimes, where deposits of magnetic iron ore have been eroded, the sands near the surface may contain such a considerable amount of magnetic disturbance as to indicate the presence of a body of iron ore, while in reality there may be such a small quantity disseminated through the sand that it could not be made to pay for its removal.

Any body of magnetic iron ore is affected by polarity, and one end of it will attract one end of the dipping needle, while the other end will attract

the opposite end. Where the body is badly broken up, this dip of the needle may be reversed several times in a comparatively short distance.

Prospecting for Petroleum, Natural Cas, and Stumen.—Among the surface indications of petroleum and bitumen may be mentioned white leached shales or sandstones, shales burned to redness, fumaroles, mineral springs, and deposits from mineral springs. Also natural gas, springs of petroleum oil and naphtha, porous rocks saturated with bitumen, cracks in shale, and other rock partly filled with bitumen. Petroleum is never found in any quantity in metamorphic rocks, but always in sedimentary deposits. Bitumen can be told from coal, vegetable matter, iron, manganese, and other minerals, which it sometimes closely resembles, by its odor and taste, also by the fact that it melts in the flame of a match or candle giving a bituminous odor. (Iron and manganese do not fuse, and coal and vegetable matter burn without fusion.) Bitumen is also soluble in bisulphide of carbon, chloroform, and turpentine, usually giving a dark, black, or brown solution. Frequently, springs or ponds have an iridescent coating of oil upon the surface. Sometimes iron compounds give practically the same appearance, but the iron coating can always be distinguished from the oil by agitating the surface of the water, when the iron coating will break up like a crust of solid material, while the oil will behave as a fluid, and tend to remain over the entire surface even when it is agitated.

Frequently, bubbles of gas are seen ascending from the bottoms of pools These may be composed of carbureted hydrogen or natural gas, or creeks. which is a good indication of the presence of petroleum or bitumen; they may be composed of sulphureted hydrogen or carbonic acid gas. Carbu-Carbureted hydrogen can be distinguished by the fact that it burns with a yellow luminous flame, whereas sulphureted hydrogen burns with a bluish flame, and carbon dioxide will not support combustion, but, on the contrary, is a

product of combustion.

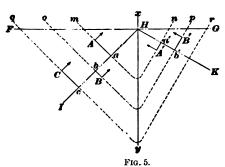
When carbureted hydrogen gas is discovered ascending from water, the bottom of which is not covered with decaying vegetation, it is almost a certain sign that there is petroleum or bitumen somewhere in the underlying

or adjacent formations.

If natural gas or bitumen is found upon the surface of shale, it is probable that the material ascended vertically through cracks in these rocks from porous strata below; while if it is found in connection with sandstones, it is probable that the material was derived from the porous sandstone itself. This is especially liable to be true if the sandstone has a steep pitch.

As a rule, deposits of bitumen or petroleum occur in porous formations overlaid by impervious strata, such as shales, slates, etc. Anticlines are more liable to contain such deposits, though they are not absolutely necessary to retain them, as at times portions of the underlying porous strata have been rendered impervious by deposits of calcium salts, silica, etc., and hence the petroleum or bitumen will be confined to the porous portions. Natural gas also occurs under similar conditions, but usually in anticlines

Construction of Geological Maps and Cross-Sections.—After the surface examination of a property is complete, the data should be entered on the best map procurable, or a map constructed. The scale depends on the size of the property, the complexity of the geological formation, the value of the property, and the material to be mined from it. The amount of work that it will pay to put on the survey will depend largely on the value of the property, more detail being justified in the case of high-grade properties. If a property 1,200 ft. × 3,000 ft. (the size of four U. S. mining claims) were to be surveyed and mapped with a scale of 1 in equal to 100 ft., the map would be $12 \, \text{in.} \times 30 \, \text{in.}$ A vein of strata 10 ft. wide on this map would appear as to of ne 12III. X sorin. A vein of strata to it, whose of this map would appear as 790 an inch wide, which is about the smallest division that could be shown with its characteristic symbol; for greater detail, a larger scale, or larger scaled sheets of the most important portions of the deposit, will be necessary. If the geologist constructs the topographical contour map, he can take notes on the geology at the same time. When the boundaries of the property are being surveyed, certain points should be established, both vertically and horizontally, as stations in future topographical work. map is on government surveyed land, the government lines may be used for horizontal locations, but it will be necessary to determine the elevation of the different points. If the property is much broken, it is well to run a few lines of levels across it, to establish points from which to continue the work. This work is usually done with a V level and chain, the other details being subsequently filled in with a transit and stadia, the levels of the other

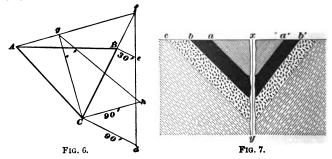


points being taken either by using the transit as a level, by vertical angles, by berometric observations. or by means of a hand level. Where lines of levels are run acros the property in various directions, it is best to run them in such a. direction that they will cross the strike of the strata as nearly at right angles as possible, so that the profile thus de-termined may be used in constructing a crosssection. Sometimes, for preliminary work, simply a sketch map is all that may be neces-

All of the outcrops and exposures, together with their proper dip,

sary. All of the ductops and capositics, oggested with the property should be entered on the map.

To Obtain Dip and Strike From Bore-Hole Records.—Before the results obtained from bore holes are available for use in map construction, the dip and strike of the various strata must be ascertained. The process, in the case of stratified rock, is as follows: If three holes were drilled, as at A, B, and C, Fig. 6, each intersecting a given bed, the strike and angle of dip of the back way, he obtained by reducing the results from the three holes to a plane bed may be obtained by reducing the results from the three holes to a plane passing through the highest point of intersection, which is at A. The hole B intersected the bed at the distance Be, and C at the distance Cd below the point A. By continuing the line CB indefinitely, and erecting two lines Bepoint A. By continuing the fine CB inclinately, and electring two lines CB and CB perpendicular to it, each representing the distance from the horizontal plane through A to the intersection of the strata, two points in the line de are obtained, which line intersects CB produced at f; f is one point in the line of strike through A. In order to find the angle of dip, the perpendicular CB is dropped from the deepest hole C upon the line of



strike Af. The distance Ch, equal to Cd, is laid off at right angles to Cg, when the angle Cgh gives the maximum dip. The results obtained from bore holes may thus be reduced to such form that the dips can be projected on the surface to obtain the line of outcrop for each stratum. Bore holes also furnish data for constructing underground curves in cross-sections of stratified rocks, and in locating the probable outline of ore bodies in other formations.

Having recorded on the map all exposures, whether surface or those obtained from underground work, draw the line of strike and the outcrops. Also construct a cross-section. If the vein is perpendicular, the outcrop will be a straight course across the map. If the bed or seam is horizontal, the outcrop will correspond with the contour line. For beds or veins dipping

at any other angle, results between these limits will be obtained.

If the property being examined is cut by synclines or anticlines, the dips will not all be in the same direction, and if there is a dip along the axis of the synclines or anticlines, the construction of the map will be considerably complicated. Fig. 5 represents a plan or map on which there is an axis xy toward which the strata dip from both sides. Outcrops are indicated at A, B, C, A', and B', each having a dip in the direction of the arrow. The lines mn, op, qr are contours. If the cross-section were constructed on the line FG, perpendicular to the axis xy, the various beds or deposits would be **cut** at such an angle as to show a thickness in the cross-section greater than that which actually exists. In order to show the actual thickness for each seam, the cross-section must be taken along the line perpendicular to the strike of the strata, which, in the present case, is along the line IHK. other words, the cross-section must be constructed in two parts. Where a general sketch is all that is necessary, a single cross-section with notes correcting the thickness of the seams may answer.

In order to construct the cross-section IHK, the outcrops A, B, C, A', and B' must be projected to the points a, b, c, a', and b', this projection being along their contours. If the points on the line of the intended cross-section were not upon the contour, it would be necessary to project them on the plane of the cross-section, as shown in the figure, and then from the dip of the strata and the difference in elevation to obtain a corrected point along the line IHK. The cross-section is constructed as shown in Fig. 7, each seam having its actual thickness as shown at the outcrop. If the upper surface of the cross-section is not a true profile of the surface, and the points are not projected in the plane on the cross-section, on this cross-section, according to their dips, there is considerable danger of exaggerating their

thickness one way or the other.

On mine maps, the supposed course of the beds should be sketched in, subject to revision, as more data are brought out by later development work. Even in the case of stratified rocks, it is difficult to form a definite idea as to the underground conditions from surface indications, and, in the case of metamorphic or crystalline rocks, it is absolutely necessary to determine the underground conditions by drilling, or actual development work. If the property being examined is liable to become a large and valuable mining property, the original survey should be tied to monuments or natural landmarks, so that it can be checked by future observations, and these monuments or landmarks should become the basis of future and more careful mining surveys.

Some of the advantages of a careful geological examination of a property are that other materials of economic value would probably be discovered, if any should exist on the property; also, such an examination of the property gives information as to the drainage system of the country that may be of great advantage in laying out the mine, and future exploration by drilling or sinking can be done to better advantage after a careful surface

examination.

Sampling and Estimating the Amount of Mineral Available.—In many cases, it is samping and extinating the amount of mineral Available.—In many cases, it is necessary to do some development or exploration work before fair average samples can be obtained. The samples as taken should fairly represent the material as it will be extracted. Such gangue as cannot be separated from the ore in mining, or slate that would be sold with the coal, should be included in the sample. When sampling any property it is well to divide the deposit up into blocks, and sample each one separately. The samples may then be assayed and an average obtained later, or the different samples may be mixed and an average assay obtained. The amount of material broken for sample may vary from a few pounds to many tons deeming on broken for sample may vary from a few pounds to many tons, depending on the nature of the material under consideration. Large samples may be reduced by shoveling (that is, taking a proportionate number of shovelfuls for the sample, as every third or fourth shovelful). After the sample has been partially reduced, the operation may be carried on by quartering, which may be described as follows:

The material is shoveled into a conical pile by throwing each shovelful on to the apex of the cone. After this, the cone may be reduced by

scraping it down with a shovel, passing slowly around it. If the amount of material is small, a flat plate may be introduced into the cone, and the pile flattened by revolving the plate. The pile is then divided into quarters by drawing lines across it. After this, two alternate quarters are scraped by drawing lines across it. After this, two alternate quarters are scraped out and shoveled away, and the other two quarters are left as the sample. The process may be repeated until the block has been sufficiently reduced. In shoveling away the discarded portions, care should be taken to see that the fine dust under them is brushed away also, as they often contain fine and valuable mineral that would unduly increase the value of the resulting sample. When the sample consists of only a few pounds, it may be reduced by means of a riffle. Large samples consisting of several tons are sometimes sent to sampling works to be reduced by automatic sampling machines. If the property being examined is a mine in active operation, samples may be taken from the working faces and also from cars loading chutes etc. be taken from the working faces, and also from cars, loading chutes, etc. Usually the samples from the face are kept separate from those from the cars and loading chutes, the latter being intended as a check on the former. In the case of ores of the precious metals, large samples are sometimes taken and used for mill runs.

Stock piles, or dumps, may be roughly sampled by taking pieces from intervals over the surface, being careful to obtain a fair average of coarse These samples are quartered down and fine material, and of rock and ore. and assayed, but if a close valuation is desired, it will be necessary to drive cuts or tunnels through the mass, and to take a certain amount, as every fifth or tenth shovelful, for the sample. When sampling dumps of fine material (as, for instance, tailings) it is possible to take samples from the pile by means of a drill, an auger 1 in. or 2 in. in diameter usually being

employed for this purpose.

The human factor always plays a large part in the value of a sample as finally selected, and hence it should be taken by a man who has had considerable experience in this class of work. For this reason, it is best to employ a mining engineer. One not accustomed to sampling very rarely undervalues a property, owing to the fact that it seems to be human nature to pick up a rich piece of ore or coal, rather than the barren gangue material or slate.

When only surface exposures or shallow prospect openings are available, it is impossible to determine the amount of ore in sight, or to form more than a guess as to the size of the deposit. It is not safe to count any ore in sight unless it is exposed on at least three faces. Ore that is exposed on one or two faces can be counted as probable ore, while slight exposures can be

counted only as chances indicated.

The amount of material available in coal deposits can be estimated much closer than in the case of ores. If a seam is penetrated by a number of bore holes, or by workings extended over a considerable area, it is fair to estimate that the material will run practically as exposed for a considerable area; but especially in the case of bituminous coal, it is a comparatively easy matter to form some estimate as to the amount of material available.

When dealing with ores, it is impossible to form reliable estimates, owing to the fact that horses or other masses of rock may be exposed at any point, and the ore bodies themselves are usually very irregular, hence it will be

necessary to do careful blocking out before making any estimates.

When estimating the amount of mineral available, only that portion which can actually be removed in stoping should be counted, and if the seam is so narrow that it is necessary to break material from the walls, or if there are masses of country rock that have to be removed with the ore, the expense of removing them should be estimated and deducted from the value of the ore.

DIAGRAM FOR REPORTING ON MINERAL LANDS.

The following diagram will be useful as a guide in making out a report on a mining property:

1. Location, if on surveyed land. Nearest town or village. 1. SITUATION [1. Name. 3. Mineral district. AND SUR-4. County, state, or territory. ROUNDINGS. 2. Distance and direction from one or more points.

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DIAGRAM FOR REPORTING ON MINERAL LANDS-(Continued).
                     1. Hills or mountains.
                     2. Character of surface, vegetation, and timber.
   TOPOGRA-
                     3. Streams and water supply.
    PHY.
                   4. Elevations.
                                                    1. Stratified.

    Rocks.

                                                    2. Crystalline.
                                                    3. Igneous.
                                                     Anticlines or synclines.
                                   Axes.

    Number.

                                                    2. Strike.
                                   3. Faults.
                                                    3. Dip.
                                                    4. Throw.
                     1. Struc-
                                                    1. Number.
                       ture.
                                                     2. Strike.
                                                    3. Dip.
4. Filling.
                                   4. Dikes.
                                                    5. Throw.
                                                     1. Number and size.
                                                     2. Location.
                                   Horses.
                                                    3. Material.
                     2. Geological period.
                                                     1. Reported.

    Reported.

                                                     2. Measured.
                     3. (a) Coal ( 1. Number.
                                                                       2. According
                                 2. Thickness.
                                                     3. Average.
                                                                         to meas-
                                                     4. Uniformity.
                                                                         urement.
                                                     1. Number.
                                                     Character.
                                                     3. Strike.
                                                     4. Dip.
                          or
                                                     5. Width. \begin{cases} 1. & \text{Maximum.} \\ 2. & \text{Average.} \end{cases}

    Veins.

                                                     6. Vein filling.
                                                     7. Ore chutes.
                                                     8. Walls.
                                                     9. Throw of walls.
                         (b) Ore
  3. GEOLOGY.
                                                     1. Number.
                        bodies.
                                                     2. Walls.
                                                     3. Strike.
                                    2. Beds
                                               or
                                                     4. Dip.
                                                     5. Length.
                                      lenses.
                                                     6. Height.
                                                     7. Maximum width.
                                                     8. Average width.
                                             1. Color, external, powder.
                                             2. Luster.
                                             3. Clearness from clay or sand, shale.
                                             4. Sulphur.
                      4. (a) Quality of
                                             5. Resin.
                        coal, specimens,
                                             6. Firmness, size of lumps, air slaking.
                        appearance
                                             7. Cleavage or fiber.
                        in mine, in cars,

    Coking.
    Color of ashes.

                        benches.
                                             10. Use: Gas, steam, domestic, forge,
                                                 metallurgy.
                                             11. Analyses or assays.
                              or

    Shipping.

                                             Concentrating.
                                             3. Metals or minerals.
                         (b) Ore.
                                             4. Gangue.
                                             5. Impurities.
                                             6. Assays or analyses.
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DIAGRAM FOR REPORTING ON MINERAL LANDS-(Continued).

1. History. 4. MINING. 2. Mine.	1. Dates of opening, abandoning, reopening, number of mines and names. 2. Ownership. 3. Superintendence. 1. Shaft, slope, or tunnel. 2. Extent of 2. Depth below water level. workings. 4. Extent of levels. 3. Number of levels. 3. Water pumps, size, and kind, water cars, number and size, natural drainage. 4. Ventilation, natural, furnace, fan (forcing or drawing out), sufficient or insufficient. 5. Lighting, system used. 6. Powder, kind and grade used. 7. Explosive or noxious gases. 8. Coal-cutting machines and power drills. 9. (a) Mode of working, holding under, shearing, blasting, or wedging. (b) Mode of Working, holding under, shearing, blasting, or wedging. 4. Caving. 5. Rooming with or without timber. 6. Square sets. 10. Rooms, or stopes, pillars, dimensions, and general plan. 11. Timbering, timber trees. 12. Roof, or hanging wall, strong or weak, air slakes or not. 13. Floor, or foot-wall, hard or soft, creeps or not. 14. Roads, rails, and cars. 15. System of underground tramming. 16. System of hoisting. 17. Locomotive. 18. Latent of levels. 19. Locomotive. 19. Lightling, water cars, number and size, and kind, water cars, number and size, and for insufficient. 20. Lightling, system used. 3. Extent of levels. 4. Caving. 5. Rooming with or without timber. 6. Square sets. 10. Rooms, or stopes, pillars, dimensions, and general plan. 11. Total depth. 12. Men. 12. Mules. 13. Electricity. 14. Carge. 15. Skip. 16. System of hoisting. 16. System of hoisting. 17. Locomotive. 18. Cars.
5. Maps and Drawings.	3. Columnar. { 2. Coal bed or other deposit. ngs, works, or machinery. 1. Scale. 2. North line, magnetic variations. 13. Date. 4. Maker. 5. Can buy, take, borrow, or have
6. CONCENTRA- TION. 1. Hand pick 2. Cobbing at 3. Magnetic. 4. Mechanics	nd picking.

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DIAGRAM FOR REPORTING ON MINERAL LANDS-(Continued).
                    1. History, ownership, etc.
                     Number.
                    3. Character of ovens.
                     4. Dimensions.
                    5. Construction, materials, etc.

    Charge, quantity, etc.
    Working.

7. COKE
         OVENS.
                     Operations.
                                      3. Discharging, quenching.
                    7. Repairs.
8. Quality of product. (Assa)
9. Disposition of by products.

1. In heaps.
2. In stalls.
                                              (Assays, if any.)
                                    3. In kilns.

    Roasted.

                                    4. By mechanical calciners.
                                    5. Number and dimensions of roasters.
                                                        1. Base bullion.
8. METALLUR-
                                                        Matte.
  GICAL WORKS
AND TREAT-
                                     1. In shaft fur-
                                                        3. Metal.
   AND
                                       nace to
                                                        4. Number and dimen-
   MENT OF ORE.
                                                           sions of furnaces.
                                                           Metal.
                                     2. In reverber-
                                                           Matte.
                     Smelted.
                                       atory furnace
                                                        Number and 'dimen-
                                       to
                                                           sions of furnaces.
                                                        1.
                                                           Metallic zinc.
                                                           Mercury.
                                     3. In retorts to
                                                           Number and size of
                                                           retorts.

    Smelter.

                                                           Concentrator.
                                       1. As mined to
                                                           Sampling works.
                                                           4. Jobber at
                                                           1. Smelter or furnace.
                                         As
                                               concen-
                                                           Sampling works.

    Shipped.

                                         tratesor coke.
                                                           3. Jobber at
                                                           1. Refinery.
                                       3. Metal or
  9. DISPOSITION
                                                           2. Smelter.
                                               matte to
    OF PRODUCT.
                                                           3. Jobber at -

    Distance.

                                       Roads.
                     2. Shipment.
                                       Railroads.
                                       Navigation.
                                         1. Capacity.
                                                      1. Daily, weekly, or month-
                                                         ly, in tons.
Yearly in tons.
                                         2. Actual.
                    1. Production.
                                                      Average.
                                        (1. Whole number of workers.
                                         2. Number of workers in each class.
   10. STATISTICS.
                    2. Labor.
                                        3. Number of horses or mules.

    Timber.
    Tools.
    Fuel.

                                         4. Qil.
                                         Powder.
                                                     1. Day, different classes.
                                                     2. Contract or piece, yard or
                                         6. Labor.
                                                        ton.
                     3. Prices.
                                           Carriage
                                         8. Local sales of product.
                                                               1. Machinery.
                                                               2. Buildings.
                                                               3. Roads, tracks, etc.
                                         9. Value of plant.
                                                               4. Rolling stock.
                                                               5. Supplies.
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DIAGRAM FOR REPORTING ON MINERAL LANDS-(Continued).

	1. Power plant. 1. Power plant. 3. Air compressors. 4. Steam and gas engines. 5. Electric plants.
	1. Smith's Shop. 1. Power for. 2. No. of forges. 3. Steam hammers. 4. Other tools. 1. Power for. 1.
11. SURFACE PLANT.	2. Shops. 3. Lathes. 4. Other machines. 5. Benches and vises
	3. Powder houses. 4. Offices. 3. Machine shop. 4. Offices. 5. Drill presses. 5. Drill presses.
	5. Dry or change houses. 6. Storehouses. 7. Boarding and dwelling houses. 8. Stables. 6. Other tools. 7. Benches and vises
	9. Shaft houses. 10. Tipples. 11. Pockets or one hing
	12. Company store. 13. Timber yard and plant for preparing timber. 1 City or commercial 2. Sufficient or insorving sufficient.
	14. Water. 3. Pressure. 1. Quality of water. 2. Sufficient or insufficient.
	2. Company service. 3. Gravity system. 1. Direct. 4. Pumping sys- voir or voir or
•	tem. stand pipe. 1. Character. {1. Gas. 2. Electric.
	15. Lighting. 2. Origin. 1. Commercial plant. 2. Company plant. 3. Sufficient or insufficient. 1. Steam engines.
	16. Hoisting or winding plant. 2. Compressed air engines. 3. Oil or gasoline engines. 4. Electric motors. 5. Water motors.
	1. Railroad. 1. Railroad. 1. Railroad. 1. Rouge. 2. Total length. 3. Size of cars. 4. No. of cars. 5. Power used. 6. No. of motors.
	17. Surface transportation. 2. Wagon roads. roads. 2. Length. 3. No. of wagons and teams.
	3. Traction engines. 1. Size and capacity of. 2. No. of wagons for.

DIAGRAM FOR REPORTING ON MINERAL LANDS—(Continued). 12. MISCELLANEOUS.

Gross. 1. Yearly income, last year, or for any year. 12. Net. Average cost per lb., or ton of material. Quality of ore or product.
 Amount of ore or f1. Gross. 1. Deposits 3. Merits of of value. material in sight. \ 2. Net. 3. Value of material in sight. property. Value of plant and works. 1. Continue present system. 13. CONCLU- Change system to –
 Ship as mined. SIONS. 4. Advice. 2. Disposition 2. Concentrate, or coke and of product. ship. 3. Smelt and ship. Troubles. 2. Labor. 3. Supplies. Local considerations. 4. Climate. Shipment facilities. Markets.

OPENING A MINE.

The location of the surface plant and the mine opening depend on the formation of the deposit primarily, and secondarily on the facilities for transporting the product to market. It is impossible for one not on the ground, and unfamiliar with natural or railroad transportation facilities in the neighborhood, to give an idea as regards the second consideration. In regard to the first consideration, the following observations will be found of value:

When the seam or vein outcrops within the limits of the property and is flat, a water-level drift is the best method of opening it. If it has any considerable inclination, it should be opened by a slope, or by a tunnel driven across the intervening measures. Where the deposit has an inclination of but from to 1° to 1°°, the water-level drift is generally used, and the mainaulage entry is opened at the lowest accessible point on the outcrop which insures free drainage and a favorable grade for haulage. When the outcrop dips into the hill, the drift is usually commenced a few feet below the outcrop terrace, and driven on a slight up grade until the normal dip is reached.

crop terrace, and driven on a slight up grade until the normal dip is reached.
When the inward dip is too strong, the better plan is to sink a shaft in the
center of the basin, provided the depth is not too great and the amount of
water to be pumped is comparatively small. If the inward dip to the center
of the basin does not exceed a total of 25 ft. difference in level, a drift may

be used and drainage be effected by a siphon.

Water-level drifts are only profitable where the inclined seam is exposed in ravines or gorges eroded across the strike of the measure, or where the vein can be reached by a short tunnel from the surface to the seam across the measures. This is often the case when the seam dips with the hill, when the dip is against the hill, the tunnel is generally a long one. While the expense of operating a mine opened by a long tunnel is less than one opened by a slope or shaft, owing to cheaper drainage and haulage, when the coal above water level is exhausted the tunnel is almost worthless. When the seam is inclined and is accessible at no point along its outcrop low enough to furnish sufficient lift or breast length, it should be opened by a slope or shaft. Or, if the seam is flat and does not crop on the tract, a shaft is the only method of working it, unless it lies so near the surface that it can be stripped.

Where a seam has a dip of 20° or more, and is brought close to the surface by an anticlinal axis or "saddle." a "rock slope," or, in other words, a tunnel dipping the same as the seam may be started from the surface, and, when the seam is reached, may be continued to the desired depth in the

In sinking slopes for coal mines, it is customary to sink an airway alongside of and parallel with the slope, with a pillar of about 10 yd. between. The slope for coal mines is usually sunk so that there is a "lift" of from 100 to 110 yd., and then gangways are turned off on each side. The term 'lift" in this connection means the length on pitch that breasts or rooms, driven at right angles to the gangway, can be driven in good coal, quent lifts are usually from 80 to 100 yd. long. Subse-

Opening Up a Gold Mine.—The following description of the method of opening up a gold mine, by Mr. S. A. Josephi ("Mines and Minerals," February, 1900), will also apply in general for the opening of any inclined narrow ore deposit: The equipment for the top of shaft for the preliminary work consists of three pieces of timber, either sawed or rough hewn, 12 to 16 ft. long. sists of three pieces of timber, either sawed of rough newn, 12 to 16 ft. long, 8 to 10 in. in diameter, arranged as a tripod; they should be strongly bolted together, a pulley hung from the center, through this a rope passed with a bucket fastened to the end entering the shaft, and a horse hitched to the other end. This equipment is called a whip, and is sufficient for the first 100 ft. in depth. In locating the shaft, care should be exercised in placing it where there is ample dump, or ground for waste or valueless vein matter. Should the character of the surface not admit of sufficient ground for this purpose, have collar (or top) of shaft elevated 10 or 12 ft., and throw waste around the outside of same until filled up solid.

The timbers should be square sets made of rough or square timbers.

The timbers should be square sets, made of rough or square timbers, preferably the latter, $8 \text{ in.} \times 8 \text{ in.}$; divide the shaft into two compartments $4 \text{ ft.} \times 4 \text{ ft.}$ each, one for the bucketway, the other for the ladderway. Where

air is bad, board up the ladderway to aid the circulation. The sets should be not less than 4 it. and not over 6 ft. apart, in the clear.

Sink on the dip of the vein, and keep a careful record of the location, width, and value of ore body, until the depth of 100 ft. is attained; here place station sets 8 ft. high, start levels each side of shaft, and, if there is water in the shaft, a sump 16 ft. to 30 ft. deep should be sunk. The sump should be built in the same manner as the shaft, so that it will serve as a

continuation of same when greater depth is wanted.

Levels should be run on both sides of the shaft sufficiently long to determine length of the ore chute, and also to determine the existence of other ore chutes in the vein. This development work should be an indicator of the strength, value, and permanence of the property; it is now ready for another examination by competent authorities, to determine the above conditions. Should their verdict be favorable, continue the shaft to the depth of an additional 100 ft.; if water is found in but small quantities, this can best be done by replacing the whip with a whim; this runs by the same horsepower, costing in the neighborhood of \$100. It is well adapted to put the shaft down 250 ft.

When the shaft is down 200 ft., start levels as at the 100-ft. depth, provide

sump, and drift both ways upon the vein, proving up ore bodies as before.

Thus far the cost has been slight. The shaft, including timbers, supplies, and contingent expenses, should not cost over \$20 a foot, a total of \$4,000; the drifts \$6 a foot, say 200 ft. each way from shaft on both levels, a total of \$00 ft. or \$4,800; total, \$8,800, less amount received from mineral extracted in subting and drifts \$6.00 ft. sinking and drifting, which is usually small.

Now it is to be decided what further amount the owners are willing to expend, and how extensively they desire the mine opened up before the actual extraction of ore is to commence. We will put the depth of shaft at

500 ft., the drifts the full length of the claim, usually 1,500 ft.

For this purpose, a shaft house should be built, say 40 ft. × 60 ft., with ore house, say, 40 ft. × 40 ft. The equipment should be a 40 H. P. engine and a 60 H. P. boiler (if a large flow of water is encountered, an additional boiler and pump must be provided), the shaft continued to the above stated depth, and levels extended at each 100 ft. It will also be advisable to make upraises at the farthest point practical from the shaft, on each side, connecting each These upraises should level with the other, and extending to the surface. be made in ore, and are valuable both for ventilation and escape for men, They should be furnished with in case of accident to or near the shaft. ladders. The machinery, shaft house, and skip, with which all incline shafts should be equipped, will cost about \$4,500. The additional 300 ft. of shaft, including contingent expenses of engineers, fuel, etc. will cost \$40 a foot, or \$12,000; the drifts, \$6 a foot. The upraises, being on ore, should pay for the labor.

It is prudent to estimate the cost of thoroughly opening up a gold mine to

between \$40,000 and \$50,000, which fact probably originated the remark at "it takes a gold mine to make a gold mine." This is practically true, and no one should attempt to engage in the mining business, as a business, at thout both money and a willingness to use it. More failures can be tributed to insufficient capital for development than to any cause save hismanagement.

SHAFTS.

Shafts and tunnels may be, first, temporary, or those that are simply driven for exploration purposes, and are not to be used for any great length of time; second, permanent, or those that are driven for a specific purpose

and usually have a definite predetermined capacity.

Form of Shaft.—In the United States, shafts are usually square or rectangular in form. This is largely due to the fact that timber is used in lining such shafts. In Europe, round or oval shafts are frequently employed with

a lining of brick, iron, or masonry.

Compartments.—The number of compartments in a shaft and their arrangement depends largely on the use to which the shaft is to be put; also on the number of shafts at the property, and the depth of the shaft. Where the material to be removed is comparatively near the surface, it is usually cheaper to sink a number of 2- or 3-compartment shafts than it is to tram all the ore to one large shaft; while, in the case of very deep mines, large 4- or 6-compartment shafts are sunk, and the underground haulage extends over When the shafts are lined with timber, a stronger cona greater area. struction can be obtained by placing the compartments side by side, as shown in Fig. 1, than by placing them in the solid block, as shown in Fig. 2. When a body of material compara-

tively near the surface is being removed through a number of shafts, 2-compartment shafts are frequently employed, both compartments being used for hoisting, and separate shafts being provided for the pump column and ladderways. This reduces both the size of the shaft and

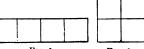


Fig. 1. Fig. 2.

the timbering necessary, and also does away with the special danger from fire that always exists when there is a ladderway in the shaft, for it is always difficult to fight fire in these special compartments.

Shaft Sinking.—As a general thing, the loose material or wash above bed rock is not thick enough to cause any serious trouble, and ordinary cribbing of heavy timber or a masonry curbing is sufficient. But when the surface is very thick or loose, and runs like quicksand, considerable difficulty is experienced. The general method of overcoming this difficulty in the past was to at once divide the shaft into the required number of compartments by heavy timbers alternating or placed "skin to skin," which had the effect of bracing the cribbing against the lateral pressure of the loose material. This method is effectual where the wash will remain solid or stand long enough to allow the timbering and cribbing to be put in. But when the

surface is thick, loose, or watery, or of quicksand, some one of the following

pecial methods of sinking must be adopte	ed:
guicksand {	"Forepoling." "Metal linings." (Forced down without the use of compressed air.) "Pneumatic"method. (Limited to about 100 ft. in depth.) "Poetsch" process. (Freezing method.)
Rock (hard or soft, but very wet)	"Kind-Chaudron" method.
Rock (hard or soft, but not very wet) }	"Continuous,"or"Long-Hole," method.

Size of Shafts.—Shafts vary greatly in size, depending on the number of compartments desired and the size of the compartments. For coal mines, they are generally from 10 to 12 ft. wide inside of timbers, and each compartment is from 6 to 7 ft. wide inside the guides. This would make the outside dimensions of a double-compartment shaft about 13 to 15 ft. wide, 17 to 18 ft. long, and a triple-compartment shaft from 24 to 25 ft. long. metal mines are generally smaller than those at coal mines, but the practice in different localities varies so that it is impossible to give general dimensions that would be of value.

The table on opposite page gives the dimensions of a few well-known shafts in different localities.

Forepoling.-When the ground is so bad that it will not stand for several days between excavation and the completion of the lining, it becomes necessary to carry the timber to the bottom of the work. This may be accomplished by using square-set shaft timbering and driving laths, or forepoling behind the timber so as to keep the soft material from running forepoling behind the timber so as to keep the soft material from running into the opening. The advantages of forepoling are that, if the shaft is being lined with square sets, it can be commenced at any point, and, if the ground is not too bad, the work can be continued by this means until solid material is encountered. When the ground is particularly bad, it may become necessary to use breast boards, which are simply boards braced against the bottom of the shaft so as to keep the material from rising into the opening, only one board at a time being removed while the material behind it is excepted behind it is excavated.

In particularly bad ground, where breast boards have to be used, the progress made is very slow. After the shaft has been put down by foreprogress made is very slow. After the shaft has been put down by fore-poling, it is sometimes very difficult to repair or replace the lining. When the forepoling method is employed in quicksand, there is considerable risk of losing the shaft altogether, owing to sudden rushes or "boils" of the material that throw the timbering out of line and fill up the shaft.

Metal Linings Forced Down.—Metal linings forced down without the use of compressed air are rarely resorted to, though in some cases they have been quite successful. If the formation contains but few boulders, it is some

FIG. 3.

times possible to force the lining down by flushing out the material from the inside with jets of water. At other times. men enter the shaft and excavate the material as the work progresses.

The pneumatic method of shaft sinking was developed from the system in use for putting down foundations for bridge piers. At the bottom of the shaft there is a small chamber called a caisson, in which a sufficient air pressure is maintained to exclude the water at all times. The shaft lining is built on above this chamber, and gradually forced down into the soil. enter the chamber and excavate the material from under the caisson as it descends.

By this method the sinking commences at once and is continued without interruption until the lining is completed to bed rock, to which the lining is joined, as shown in Fig. 3. An air compressor, which is subsequently used, is the only auxiliary machine necessary, while in the freezing process an ice machine is required.

It is best to use electric lights in the caisson; hence, it may be necessary to install a small dynamo if the company does not have an electric-light system

in operation. In the pneumatic system, the bottom of the shaft is always exposed to view, and the workmen know when they reach a solid foundation; while, in the freezing process, it is sometimes difficult to tell to what depths the pipes should be sunk so as to reach below any fissures or seams in the bed rock. In the pneumatic process, the fine material is aspirated out of the caison by the air pressure. The pneumatic process is limited to a depth of about 100 ft., as it is impossible for men to work under a greater air pressure than that which corresponds to about 100 ft. of hydrostatic pressure.

By the freezing process, pipes are sunk in the ground about the area to be frozen, as a rule, not more than 3 or 4 ft. apart. The lower ends of the pipes

TABLE OF WELL-KNOWN SHAFTS.

Remarks.	7. 6" × 12° (12° 0" × 62° 0") (1039) (12× 14° 10") downcast 12° × 12° (17° 10") (18° 1
Depth. Feet.	1,089 826 828 828 828 828 828 838 838 838 838 838
Size of Shaft Depth. Over All. Feet.	5 7 6" × 12" 12 0" × 52" 0" 6 7 6" × 12 6" 47 0" × 13 10" 4 6 10" × 10 4" 12 4" × 23 10" 3 7 4" × 10 4" 12 4" × 25" 6" 8 3 4 2" × 4 2" 5" 6" × 72" 6" 8 6 6 3" × 7 0" 23" 0" × 25" 6" 8 5 7 2" × 5 0" 23" 0" × 25" 6" 8 5 7 2" × 5 0" 23" 0" × 25" 6" 8 5 7 2" × 5 0" 23" 0" × 25" 6" 8 5 7 2" × 5 0" 23" 4" × 9 0" 5 7 2" × 5 0" 23" 4" × 9 0" 5 7 2" × 5 0" 23" 4" × 9 0" 5 8 6 4 8" × 7 0" 23" 4" × 9 0" 5 8 6 4 8" × 7 0" 23" 4" × 9 0" 6 4 8" × 7 0" 23" 4" × 9 0" 6 4 8" × 7 0" 23" 4" × 9 0" 6 4 8" × 7 0" 23" 4" × 9 0" 6 4 8" × 7 0" 23" 4" × 9 0" 6 4 8" × 7 0" 23" 4" × 9 0" 6 4 8" × 7 0" 23" 4" × 9 0" 6 4 8" × 7 0" 23" 4" × 9 0" 6 4 8" × 7 0" 23" 4" × 9 0" 6 4 8" × 7 0" 23" 4" × 9 0" 6 4 8" × 7 0" 23" 4" × 9 0" 6 4 8" × 7 0" 23" 4" × 9 0" 6 7 8" × 7 0" 23" 4" × 9 0" 6 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8
Size of Holsting Compart. ments.	5 7 6" X 12" 12" 0" X 52" 0" 12" 0" X 13" 10" 12" 0" X 13" 0"
-moOto.oN	7 0 0 7 7 7 7 2 7 0 0 4 2 2 2 2 2 2 2 2 2 3 3 3 3 3 3 3 3 3 3
Material Mined.	Anthracite Anthracite Bituminous Bituminous Bituminous Bituminous Bituminous Copper Co
Location.	No. 5 Shaft Wilkes-Barre, Pa. Hazleton Shaft Hazleton, Pa. Exeter Red Ash Co., Pa. Centennial Type General Type Centennial Eureka Utah Ontario Red Jacket Tamarack, Mich. Tamarack Tamarack, Mich. Hamilton Callumet, Mich. Butte and Boston Butte, Mont. Hamilton Iron Mountain, Mich. Salisbury Gorna and Vir- Virginia City, Nev. Gorna and Vir- Virginia City, Nev. Gransolidated Call- Gorna and Colorado Average for Large Cityple Creek, Colo. Average for Large Colorado Gordado Grandon Mo. Franklin Furnace, N. J. General Type John Mo. Franklin Furnace, N. J. General Type John Mo. Franklin Furnace, N. J. General Type
Name.	No. 5 Shaft Wilkes-Barre, P. Hazleton, Pa. Exeter Red Ash. Co., Pa. Leith Mine General Type Pa. Bituminous Centennial Eureka, Utah. Ontario Red Jacket Tamarack, Mich Butte and Boston Butte, Mont. Hamilton Fayal Iron (Co. Selisbury Grana and Vir. Virginia Salisbury Grana and Vir. Virginia City, N. Virginias and Vir. Virginia City, N. Virginias Average for Large Colorado Average for Large Colorado Average for Large Colorado Parker Shaft General Type Johlin, Mo. Combol Mines in Franklin Franklin General Type Colorado Mines in Parker Shaft General Type Johlin, Mo.

* Depth completed, 1,150 ft.

f In the clear.

are sealed or closed, and an inner tube introduced so that a freezing mixture may be caused to circulate down through the inner tube, and up through the outer tube. This freezing mixture may be either liquid ammonia gas which is allowed to expand in the outer tube, or it may be a solution of calcium chloride that has previously been reduced to a very low temperature by means of an ordinary refrigerating machine. The circulation is maintained in the pipes until the ground between them is frozen solid, after which the work may be continued as though the formation were sold rock, the material being blasted and hoisted in buckets. The freezing process may be applied to any wet formation, whether hard or soft, while the pneumatic process is applicable only to soft formations. The freezing process may be carried to practically any depth. As a rule, the freezing pipes are never sunk inside of the shaft area.

The Kind-Chaudron method is applicable only to round shafts, and is suitable for shafts passing through very wet and at the same time com-paratively soft formations. The excavation is carried on by means of a large set of boring tools armed with steel teeth, and operated in a manner similar to that employed in drilling wells by the percussive system. First, a pit or shaft 4 or 5 ft. in diameter is drilled; this is followed by a reaming bit that enlarges the hole to the desired diameter, or the work may be accom-The material removed by plished in three stages by using two reaming bits. the first bit is hoisted out by means of a sand bucket, or sludger, while that removed by the succeeding tools is hoisted out by buckets that are placed in the bottom of the first pit and kept there while the tools are in operation. No water is pumped from the shaft while it is being excavated or lined, and hence practically all the tendency that the sides would have to cave After the shaft has been excavated down to and into a solid is removed. formation, it is lined by lowering cast-iron tubbing into the hole and making a tight joint against the bottom by means of an expansive packing that is a tight joint against the bottom by means of an expansive packing that is forced out by the weight of the tubbing, or lining. After the lining is in place, the space between it and the sides of the excavation is filled with cement. When the cement is thoroughly hardened, the water is pumped from the inside of the lining, and men descend and examine the joint at bed rock. In this method, no workmen enter the shaft until it is lined through the troublesome formation.

Long-Hole Process.—The long-hole process consists in the drilling of age the holes with sand, after which the work progresses by removing the first 5 or 6 ft. of sand from the holes in the interior of the shaft, charging these holes with explosives, and fring them by electricity. Next, the holes around the boundary of the shaft are charged and fired in the same manner, and the process is continued until the bottoms of the diamond-drill holes are reached. This method is especially applicable to work in hard rock, where great speed in sinking is desired, for all the drilling is accomplished at one operation, after which the sinking progresses by simply cleaning out the

drill hole and blasting the material.

General Comparison of Methods of Shaft Sinking.—Where a shaft is sunk by forepoling, it is usually made rectangular in form. The pneumatic method may be used for either round or rectangular shafts, and the lining may be either of metal or wood. The freezing process may be used for either round or rectangular shafts, and the lining may be either timber, metal, or masonry, as the entire opening can be left open until the solid rock is reached, when the lining can be built upon it. The Kind-Chaudron method is applicable only to round shafts, on account of the fact that the hole is bored. The long-hole process is applicable to either round or rectangular shafts, but was

long-hole process is applicable to either round or rectangular shafts, but was originally introduced for sinking rectangular shafts. Sinking Head-frames.—Head-frames of very simple form are used for sinking. The skeleton of the frame is formed of heavy squared timber $(10^{\prime\prime}\times10^{\prime\prime})$ or $12^{\prime\prime\prime}\times12^{\prime\prime})$ mortised and pinned together, and braced by diagonal braces. A good height from the surface to the center of the sheave is from 20 to 25 ft. The sheave should be from 6 to 8 ft. in diameter. The sinking bucket should be of boiler iron, or of heavy hard wood strengthened by iron bands, about 3 ft. in diameter at the top by from $2\frac{1}{5}$ to 3 ft. deep. It should be suspended by a handle pivoted a trifle below the center, and it should have a pin on the rim of the bucket that will hold it in an upright position when a loose ring on the handle is slipped over it. A chain fastened to the top of the head-frame, with a hook on its loose end, is suspended so that, when hanging plumb, it is over a chute leading to the dump car. As the bucket is

hoisted out of the shaft, this chain is attached, and the engine reversed. The bucket swings over the chute, the ring holding it upright is knocked off the pin, and the rock is dropped into the chute. Rocks too large for the bucket are suspended in chains and are hoisted in that way, and removed on a truck that runs on a track inside of the head-frame, the gauge of

which is sufficiently wide to give plenty of clearance for the bucket.

Sinking Engines.—Most shafts and slopes are sunk with old engines, or
else by engines especially designed for such work, and so constructed that
they can easily be moved from place to place. In some cases where an old engine can be readily had, it is set up on temporary timber foundations and used until the shaft or slope is finished, when it is replaced by the permanent engines, and the old one is dismantled and disposed of to the best

Tools.—The old method of hand drilling is still adhered to in many instances, but it is gradually giving way to machine drilling, especially in deep shafts. When properly managed, the work is done much more rapidly and economically by the several excellent types of rock drills now on the market. They are constructed in a variety of shapes by the makers, and there are so many convenient accessories in the shape of fittings, etc. that all contractors prominent in the various coal fields possess one or more of their favorite type of drills. These drills are run either by compressed air, steam, or electric power, and in large shafts two are usually employed, so that work may not be delayed by a breakdown of one drill. The center or one side of the shaft is usually kept in advance of the rest, so as to furnish The holes are drilled from 3 to 6 ft. a sump for the collection of the water. apart, and the depth varies with the character of the rock. ficient number of holes are drilled, the drill is removed, and a cartridge made of dynamite, dualine, or some other form of high explosive is tamped in each hole. These are all fired simultaneously by an electric battery, detonating caps being placed in each charge.

To keep the shaft the required shape, if rectangular, a plumb-bob is suspended in each corner, either from the flooring on top, or from a beam laid across the cribbing, and these guide the miner in squaring the corners and If the shaft is a circular one, a plumb-line is let down in the center, from time to time, and a rod cut the exact radius is revolved around it.

it strikes the rib, the miner knows that at that point the shaft is not true.

Drainage and Ventilation.—When only a small amount of water is encountered while sinking, the best plan is to allow it to collect in a depression and bail it from there into the bucket, hoisting it the same as the rock. Where the water is excessive in quantity, a steam pump is necessary. All the leading pump works make pumps especially designed for sinking purposes, and it is not in the province of this work to mention the advantages possessed by one over the other.

When the shaft is of moderate depth, a fire burning in one corner will supply ample ventilation. To rapidly clear away smoke, a good plan is to burn a bundle of straw or shavings in one end of the shaft, and throw a couple of buckets of water down the other end. When the shaft is very deep, or when the sectional area is small, ventilation is produced either by a steam jet, or by a small fan turned either by steam or by hand. In some

cases, a fire is used that draws into a board pipe.

Speed and Cost of Sinking .- Any attempt at a general estimate regarding the speed and cost of sinking is impossible, for many reasons appreciated by the practical miner. Shafts vary so much in size, and in the character of the material through which they pass, that even if there were no other items to be considered, a general estimate could not be made. But if the ground is be considered, a general estimate could not be made. But it is a experienced contractor knows how much he can drive in a given time, and estimate for each separate shaft. The he can consequently form a good estimate for each separate shaft. The range of cost is so great that it may be anywhere from \$1 to \$10 per cubic yard of material excavated.

Slope Sinking,—A slope is an inclined plane driven down on the bed of the seam, and is generally through coal or ore, though sometimes they are driven through rock across measures to cut the seam that cannot be conveniently worked by a slope. In the latter case, it is merely an "inclined tunnel." In the former it might be termed an "inclined gangway."

A slope and an inclined plane, when mentioned hereafter, will mean an

inclined opening in coal or ore, used as a passageway for mine cars.

When the location of the slope has been decided on, erect a temporary

sinking plant; an old engine is generally used. For a short distance, varying with the nature of the ground, but usually ranging from 10 to 20 ft. on the pitch, an open cut is made, and the earth, rock, or crop coal is thrown out by hand. As soon as sufficient cover is reached, the work of undermining and timbering is commenced, and at the same time a double or single track is laid, so that the material can be taken out in a car or self-dumping skip. When the latter is used, the track is continued up a trestle some distance above the surface, and a head-sheave so placed as to draw the skip up the required distance and dump the material in a chute beneath the trestling.

The width of the slope depends on the size of the cars and the number of compartments. The most common arrangement is to divide the slope into three compartments; two large ones for hoistways, and a smaller one for pump rod, column pipe, steam pipe, and traveling way. This last is also used as an airway while sinking is going on.

In some instances, slopes have but one hoistway, laid with three rails and a travel of the being the dependent of the

and a turnout at the middle of the hoist, and some have single track with a central turnout. This may be economy in first cost, but is not in the long Collisions are apt to occur, and the breaking of a rope or the falling of coal from an ascending car is apt to cause more damage than when two compartments are used.

When several lifts are simultaneously worked, a single-track slope is used; but unless the pitch is light and several cars can be hoisted at once,

this method produces a comparatively small output.

When the dip of a slope is under 40°, the height of the slope should be about 7 ft. in the clear. When the slope dips more than 40°, unless selfdumping skips or gunboats are used, a cage is necessary, and then the height must be made greater.

The sinking of a slope is similar to gangway driving, and the tracks and

timbering are kept well up to the face.

The timbering is very similar to gangway timbering, except that squared timber is more frequently used (but it is not necessary) and the joints are cut with more care. On steep pitches, a heavy "mud sill" is let into the rib

on each side, to prevent the road from slipping down the pitch.

The Sump.—When the shaft or slope is completed, among the first things necessary is a sump in which to collect the drainage of the mine. This is an opening lower in the vein, when it is a pitching one, or in the rock when it is a flat seam reached by a shaft. It should be large enough to hold any excess of water that the pumps cannot handle; and the pumping machinery should be powerful enough to handle the ordinary drainage by running not over 10 hours per day. When this is the case, in an emergency, the pumps can be run continuously, and thus handle the surplus water.

Driving the Gangway.—In bituminous coal seams, the height of the gangway is governed by the thickness of the seam, and this is also true, in a certain sense, in the anthracite regions. But in the anthracite regions they are very seldom less than 6 ft. in height. In the larger seams they are from 6 ft. 6 in. to 7 ft. 6 in. high in the clear, and from 10 to 15 ft. wide. The gange of track to 7 ft. 6 in. high in the clear, and from 10 to 15 ft. wide. The gauge of track varies from 24 to 48 in. The grade should rise at least 4 in. in 100 ft., and a gutter 3 ft. wide by 18 in. deep should be cut in the coal on the low side. This gutter should be a gutter, and not a receptacle for refuse. There is no economy in a shallow gutter, or in neglecting it because it costs a few cents a day to keep it open. Some authorities advise a rise of from 6 in. to 1 ft. in every 100 ft., but they evidently do not take into consideration that so great a rise means a loss of from 26 to 53 ft. in lift at the end of a gangway a mile long, or, in other words, in the loss of from 68,000 to 137,000 sq. ft. of the area of coal to be reached by the gangway. This applies to pitching seams. Where the seam is flat, or nearly so, the gangway must, of course, be driven on a grade that best suits the formation. Turnouts constructed on each side of the shaft or slope, of a suitable length, are a necessity, if the slope or shaft is to be kept constantly supplied with coal. These turnouts vary in length, depending on the length of the cars, and the number necessary to keep the machinery in motion between trips. They should be wide enough to allow at least 3 ft. in the clear between the bodies of the cars; 5 ft. is even better. When possible to avoid it, there should be no center props between the

Levels in Metal Mines. - The cross-section of the level depends largely on the character of the ore mined, and the desired output from the deposit. In the case of precious metal mines, producing high-grade mineral from narrow veins, the levels are driven as small as possible. Immediately adjoining the

shaft there is a plat or station the full width of the shaft. This is heavily timbered and provided with a double track, but, as a rule, the levels have but a single track, and in some cases there is but a single track at the shaft, there being a turnout or switch in the level a short distance from the shaft. In this class of mines, 5 ft. \times 64 ft. in the clear would probably be the average size of a level, it being driven as small as possible. In the case of mines producing lower grade material and handling heavy tonnages from large deposits, as, for instance, in some of the iron and copper mines, the levels are driven larger, and in some instances are double-tracked, being from 7 ft. to 8 ft. high in the clear, and from 7 ft. to 12 ft. wide inside timbers; but, even in this class of mines, in most cases single-track levels 7 ft. \times 7 ft. to 8 ft. \times 8 ft. in the clear are employed with turnouts or passing points at intervals, and a double or triple track at the shaft. The levels are usually driven with a slight grade away from the shaft, so that they will drain to the shaft, and the grade will be in favor of the loaded car. In some mines where electric tramming is employed, the levels are so driven that the motor makes a circuit through the mine, following the foot-wall in one direction, and returning along the hanging wall, or one of the drifts may be in the country rock. Such systems as this are employed only in large properties handling a very great tonnage.

TUNNELS.

Mining tunnels are usually of small cross-section compared with those that occur in railroad work, it being rare that their size is such that they cannot be driven in full section, and if the ground is firm the operation of placing the lining may follow behind the work of driving. They are generally lined with timber, and in case the ground is of a soft or treacherous nature, bridged square sets and forepoling are employed, with or without breast boards, as the necessity of the case demands. When the material is firm rock, the tunnel is sometimes not lined, the roof being given an arched The various forms of timbering employed as tunnel linings are shown in the sections on Timbering.

MINE TIMBER AND TIMBERING.

Choice of Timber.—Timber used for underground supports in mines should be long-grained and elastic, and, at the same time, should not be too heavy. Oak, beech, and similar woods are very strong, but are heavy to handle, and when set in place are treacherous, owing to the fact that they are shortgrained and not elastic, so that, though strong, when they do break, they break without warning. Mine timber is placed, not with the intention of ultimately resisting the great pressure of the earth, but so that it may keep any loose pieces in place and also to give warning to the workmen, thus enabling them to escape before a fall occurs. For this reason, pine and fire are, as a rule, better for mine timbering, as they combine a fair amount of strength with considerable elasticity, and hence give warning long before they break. Very elastic timbers, such as cypress, willow, etc., are, as a rule, to be avoided, on account of the fact that they will simply bend like a bow, without offering the necessary resistance to hold the material in place for a short time.

Preservation of Timbers.—The character of the ventilation in a mine has considerable effect on the life of any timber supports. Damp stagnant air will cause mold and fungus growth, which will be followed by the destruction of the timber through decay or dry rot. All timbered openings should be well ventilated, and provision made for the speedy removal of damp hot

air, such as commonly occurs around pump rooms and along steam lines.

Water is a good preservative, as it washes off the spores of the fungi as

as was as they are formed, and sometimes shaft timbers are kept wet on
account of the preservative action of the water.

Timber may be also preserved (1) by a solution of common salt and
water; (2) by impregnating the wood with such metallic substances as sulphates, of copper, iron, etc.; (3) by impregnation with the chloride of magnesium or zinc; (4) by creosoting; (5) by coal tar; (6) by carbolineum.

A solution of 1 lb. of salt in 4 or 5 gal. of water gives a cheap and easily

applied preservative with which the timber should be thoroughly soaked.

Sulphate of iron is economical and effective. In the zinc process, a solution of I part of liquid chloride of zinc (Sp Gr. 1.5) mixed with 35 gal. of water creosote is forced into the wood by pressure. Impregnation with crude oil is effective, but it has the disadvantage of making the timber very inflammable. Creosote acts in a threefold manner: (1) It fills the pores and prevents saturation by water; (2) it destroys organic life; (3) the carbolic acid that it contains coagulates the albuminoids and prevents decay. Painting with liquid tar is effective, but makes the wood very inflam mable. Painting with ordinary whitewash is also said to give good results. Carbolineum is said to be effective, but is quite expensive. It is applied with a brush, or by steeping in a tank; 1 gal. will cover 300 to 400 ft. of timber.

Professor Louis, of England, has shown that preservatives decrease the It is applied with

strength of timber from 8% to 20%, depending on the process used.

The following table gives the results of tests made by different methods of treating wood at Saint Elroy, France, and recorded in 1890:

TESTS OF PRESERVATIVES FOR MINE TIMBER.

Name of Preservative.	Relative Preservative Effect.						
Name of Treservative.	Oak.	Fir.	Pine.	Beech.	Birch.	Poplar.	
Tar Chloride of zinc Sulphate of copper Sulphate of iron Creosote	27.8 10.5 42.1 18.0 1.7	263.5 50.0 12.0 12.5 2.5	87.5 26.3 8.0 4.2 4.4	105.4 18.6 1.8 4.7 0.6	26.2 52.5 2.5 3.7 3.3	150.5 34.7 15.5 2.9 1.3	

The simple removing of the bark, under some circumstances, seems to be advantageous, but, in some woods, if the bark is removed, the sap wood should also be removed. In many cases, the sap wood of coniferous trees is as strong or stronger than the heart wood, and for this reason it should not be removed. Also, in the case of many coniferous trees, the bark seems to act as a protection to the timber in the underground workings. If it becomes necessary to reduce the size of the individual sticks, it is usually better to split them than to saw them, especially in the case of wood from coniferous trees, as this does not destroy the sap wood or unduly injure the grain or fibers of the stick. Generally speaking, mine timbers last longer when kept wet, and, on this account, some of the mines in Europe have introduced a system of pipes for spraying the timbers in dry portions of the mine. When timbers are alternately wet and dry, they are destroyed with amazing rapidity. Timber should be probed from time to time to ascertain its condition, as timbers may appear sound on the outside when the heart is to condition, as timbers may appear sound on the outside when the near tecompletely destroyed by dry rot. In selecting props, the principal points to be observed are: Straightness, slowness of growth as indicated by narrow annular rings, freedom from knots, indents, resin, gum, and sap. They should also be well seasoned before use. With these precautions and proper mine ventilation, fungus growth may generally be obviated and durability insured.

Placing of Timber.—The individual sticks should never be weakened by cutting mortise and tenon joints. The pressure should be evenly distributed over a number of sticks, and not concentrated or centered at one point. Centers of revolution should be avoided. The individual sticks should be placed in the direction of the strain that they are to resist, so that they will be subject to compression along their length rather than to a transverse The individual sticks should be so placed, and the joints so formed, that the pressure tends to strengthen rather than weaken the structure up to the crushing strength of the timber. In the case of large stopes, the timbering should be done according to some regular system, while, at the face of coal mines, single props or posts are usually found better, owing to the fact that their duty is only to support the loose portion of the roof for a limited time. Probably the most important point is to timber in time, before the rock becomes broken or begins to settle.

It seems generally agreed that the main weight in mines comes nearly at ight angles to the bedding, and that the props should be mainly set in that If the deposit is horizontal, the weight generally comes vertically; irection. out if the deposit is inclined, the weight comes at a right angle to the inclina-Some authorities hold it as a principle that all props should be set at a rectangle against the main pressure. Others, in order to guard against possible side thrusts and a tendency of the ordinary weight to ride to the dip in inclined deposits, purposely cause a sufficient number of props to be set slightly deviating from the common axis.

Sawyer fixes a maximum and minimum slope for the props, varying with the rate of dip. He makes this maximum slope of the props one-sixth that

of the dip, and the minimum slope one-third of the one-sixth.

Props are usually set with the butt end downwards, but not always. Having the butt end upwards adds a trifle to the weight on the lower end, but the larger size at the top should lessen the liability of its being split by a coupling resting on it, and also gives more surface for abrasion in hammering up against a rough roof. Both ways may therefore have advantages according to the circumstances. The butt end downwards, with air circulating, is the way Molesworth recommends for stocking.

Size of Timber.-The general tendency at all metal mines at present is toward the use of systematic frames composed of small sizes of timber, rather toward the use of systematic frames composed of small sizes of timber, rather than toward the use of large individual sticks. The advantages are: (1) the small timber is cheaper and easier to procure; (2) it is easier to handle, and hence costs less to place in position. By making the frames according to some regular system, the individual sticks can be framed on the surface by machinery so that better joints are secured. The setting of timber can be done by less experienced help when it is all alike.

Joints in Mine Timbering.—In all mine timbering, the object is to so form the joints that no fastenings will be necessary and that the shape of the presence of the process will be successful by success will be successful the surrounding material will

pieces will be such that the pressure from the surrounding material will keep the joints tight. The reason for this is that any metal joints usually corrode rapidly in mines, and that, when it becomes necessary to replace timbering, this can be done with greater ease if the sticks are so framed that, by relieving them temporarily of the pressure from the sides and top, they can be simply lifted out of place and new ones substituted. The use of a framing machine renders it possible to frame the joints more exactly With hand-framed timbers, the joints are always than with hand framing. cut a little free to allow for any unevenness in the surface, but, if machineframed, they are sure to be of the same size. As timber does not sirink in the direction of its grain, it is evident that where the posts meet, if the caps shrink slightly, they will become loose in the space between the shoulders because if the caps are the shoulders. ders; hence, if timbers are cut green and framed to the exact size, subsequent shrinking may open some of the joints. This may be obviated by keeping the timber moist.

The method of taking timbers into a mine depends on the size and number of timbers used and on the character of the opening into the mine. In drift or tunnel mines, timbers are sent in on flat cars built especially for the purpose, or in the regular mine cars. In vertical shafts, they are usually stood on end on the floor of the cage, and lashed together and also to the

supports of the cage. Where the opening is an incline, it is the common practice to load the timbers into a skip and thus lower them into the mine. Timber should, wherever possible, be framed on the surface.

Undersetting of Props.—Props at the working face should not be set at right angles to the inclined floor of the seam, but should be underset, and the greater the inclination, the greater the underset. The amount of underset should vary with the inclination of the seam, and should not be so great that the props will fall out before the roof has tightened them.

Forms of Mine Timbering and Underground Supports.—The timbering of a mine may be divided into two heads: (1) timbering the working faces; (2) tim-

bering the roads.

The roof may be supported (a) by packing the waste places entirely where sufficient material is obtainable for the purpose, and timbering the faces and roads; (b) by partially packing the waste, by buildings or stone pillars with intervening spaces, and by timbering the face and roads; (c) by timbering the face and roads and supporting the roof in the waste places by wooden or stone pillars, but without any packing; (d) by timbering alone without any packs or walls whatever; (e) by supporting the main roads with brick arching, or by steel or iron supports.

The accompanying plates include all the common forms of mine timber-

ing and underground supports.

Fig. 1 shows a post a and breast cap b. The breast cap b is also sometiment called cap, head-block, headboard, lid, or bonnet. Sometimes the posts are placed upon blocks of wood similar to the head-blocks or headboards, the block being called a sole; at other times, two or more posts may be set upon one long block of timber called a sill. When posts are used in inclines, they should not be set perpendicular to the foot and hanging walls, but should be underset slightly, so that any tendency of the hanging wall to settle will bring the posts nearer at right angles to the walls, and so tighten them; the amount of underset should never be more than one-sixth the Where posts are set at an angle, they are usually pitch of the deposit.

placed on wedges, and, as the pressure comes on, the wedges are tightened.

Fig. 2 represents a stull a, which is used either to keep the walls of perpendicular or steeply inclined beds or veins apart, to support planking or lagging as a working platform, or as a platform upon which to pile

ore or rock.

Fig. 3 represents cockermegs, which are simply timber frames employed in coal mines for holding the face of the coal in place while it is being undercut. They are composed of a pole c extending along the face and supported by short stulls or braces a, the whole being tightened into place by the long stulls b.

Fig. 4 shows a crib, cog, check, piller, or shanty built up of timbers and filled with waste rock. It is intended to serve as a pillar and to withstand great vertical pressure, doing away sometimes with the necessity of leaving

pillars of ore.

Fig. 7 is a cribbing framed from round timbers laid skin to skin, and used

in raises or ore chutes.

Gangway or Level Timbers.—Fig. 5 is a set employed in the case of an extrawide gangway, there being a center post under the middle of the cap. This form of set may be provided with a sill when the floor of the drift or

gangway is soft.

Fig. 6 shows a form of drift set surrounded by bridging and used where such bad ground is encountered as to necessitate forepoling. A are the posts, B the caps, and C the sill of the regular set; D are upright bridge pieces; E a horizontal bridge piece separated from the set proper by blocks F so as to provide spaces H around the regular set through which the spiles or forepoles can be driven.

Fig. 8 shows a form of drift set sometimes employed in very heavy or swelling ground. This method of framing the timbers shortens each piece

and reduces the transverse strain on all the timbers.

Fig. 9 shows an ordinary drift set provided with a sollar for ventilation purposes. An additional brace b is placed parallel to the cap c, and this is covered with plank lagging a, so as to provide a passage above the regular drift, which may be used as a return air-course.

Fig. 10 is a simple form of drift set employed when the roof and walls are of soft material, but the floor material firm. It is composed of posts *l*, upon which is placed the cap *c*. The joggle cut into the cap to receive the heads of the post should never be less than 1 in. nor more than one-third the thickness of the cap. The cap is usually made of such a length that the posts l have an inclination or batter as shown in the illustration, thus giving greater strength to resist side pressure without decreasing the floor area of the drift, which may be necessary for drains, ditches water pipes, etc. at the sides of the track. When the floor is not composed of solid material, the posts l may be set upon a sill that is framed to fit the legs in a manner similar to that shown for the cap. The joggle cut in the sill should never be less than 1 in. nor more than one-third the thickness of the sill. The sill is usually composed of lighter material than the cap, is flattened on one or both sides, and is sometimes used as one of the ties to receive the track.

Fig. 11 shows a post l and the cap or collar c, used where one wall is of firm material. On one end the cap is placed in a hitch. When the collar is supported in a hitch, it is sometimes said to be needled, the operation being called "needling." The bottom of the post a is also secured in a hitch, in case there is any side pressure. To keep the surrounding material in place, lagging is necessary, as shown behind the timbers in Figs. 5, 10, and 11. In the case of running ground, the lagging is usually made from sawed material

and driven close together.

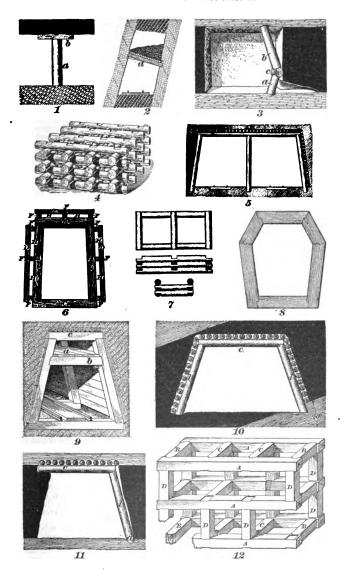


Fig. 13 illustrates a method of spiling or forepoling. a are the posts of the regular set, b the caps, and ϵ the top bridging. The front ends of the spiles from any given set rest on the bridging of the next advanced set, and the spiles for advancing the work are driven between the bridging and the set, as shown in the illustration. To force the spiles out into the ground, so as to provide room for the placing of the next set, tail-pieces i are employed; these are placed behind the back end of the spiles as they are being driven. After the spiles have been driven forward the desired amount, another set is placed, the tail-pieces knocked out, and the front end of the spiles allowed to settle against the bridging of a new set. Where the face is composed of extremely bad material, it may be necessary to hold it in place with breast boards, as shown at k, the breast boards being held in place by props l, which rest against the forward set. When breast boards are used, it is usually necessary to employ foot and collar braces between the sets, so as to transfer. the pressure of the breast back through several sets.

Fig. 14 shows a method of placing drift sets in the case of very heavy or swelling ground. a are the posts, c the sills, b the caps, d are the collar braces that bear against both the caps and the posts, while e are foor hed braces that bear against both the sills and the posts; f are diagonal braces that

are halved together and placed as shown.

Shaft Timbering.—Fig. 12 shows square-set timbering, sometimes employed for shaft lining. A are the wall plates, B the end plates, C the buntons, and D the posts. The method of framing the different parts is plainly shown.

Fig. 15 represents cribbing sometimes employed for shafts. It is composed of heavy sawed material halved together at the ends, as shown. pieces a are called wall plates, and the short pieces b, end plates. Between the compartments a partition is built up of pieces c called buntons. The ends of the buntons are let into the wall plates an inch or so, as shown in the illustration, and should be so placed that they will break joints with the individual pieces of the wall plates, thus preventing the timbers of any single set from bulging into the shaft.

Fig. 16 shows another method of framing, sometimes employed for the end and wall plates where square-set timbering is used in shafts. The end and wall plates are halved together as shown. A beveled face is often formed at D. This construction necessitates the cutting of a tenon on the end of the post F as shown. S is a $2'' \times 2''$ strip nailed along the center of the back of the wall and end plates as a support for the lagging that is placed outside of the sets. The lagging is usually composed of 2" or 3"

plank.

Fig. 18 shows the use of hangers between the individual square sets. The hangers are bolts provided with hooks on the ends, and are employed to support the sets as the work progresses, the posts serving to keep the sets properly spaced, while the hangers keep the sets tight against the posts. Hangers are not always left in permanently, but may be removed after a considerable section of the shaft has been completed.

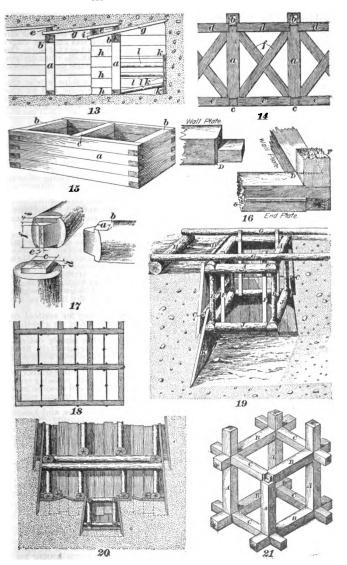
section of the shaft has been completed. Fig. 19 shows a method of applying rough square sets, made from round timber, to the sinking of a small prospecting shaft by the use of forepoling. A is the first set of timbers and J the second. The hangers are made from $2^{\prime\prime}\times 4^{\prime\prime}$ timbers F spiked to the sets and to the supports G. The supports G from which the sets are hung are placed over sills H, which are situated at a convenient distance from the collar of the shaft. D represents the legging of the first set that is usually spiked to the set. K is the forepoling that the set of the standard of the shaft of the stall places. of the first set that is usually spiked to the set. K is the forepoling that becomes the lagging between the second and third sets, and C the tail-pieces employed for forcing the lagging out into the ground. The hangers between the next two sets would be spiked to the other two timbers of the sets.

Where the bottom of the shaft is very bad, it may be necessary to use breast boards, as illustrated in Fig. 20, in which the shaft is being put down by means of square sets and forepoling with the use of breast boards.

Square Sets.—Fig. 21 illustrates one method of framing square-set timbers from sawed material for use in stopes in mines. A are the posts, B the caps and sills, while C are the sprags or stuttles. The method of framing the joints is clearly shown in the illustration. Sometimes both caps and sprags are

made of the same sized material and are framed alike.

Fig. 17 shows a method of framing round timbers for square sets. The dimensions f and c are usually made about 10 in., d, e, and i, each 2 in.; a depends on the diameter of the post; b is usually cut down to an angle of about 45°.



Landings, Plats, or Stations.—Fig. 22 is one method of timbering a plat or station. The regular square-set timbering of the shaft is continued past the station and the heavy stull or reacher a put across at the bottom of the station. The posts b are bolted against the posts of the sets and the cap c placed on top of them. After this, the wall plates are cut out between the posts b, and the station opened and timbered as shown in the illustration. The height of the station is gradually reduced to that of the drift or level connecting with it.

Fig. 22 represents a method of timbering a level in a slope where the ground is so firm that only stulls are employed in the slope and at the station, the timbers all being secured in hitches or by stulls. a represents the stulls and c the timbers that are spiked to the stulls and carry the stringers for the car track. b represents the car track from the level that is

brought across above the skip track.

Special Forms of Supports. Fig. 24 shows a stone arch which as a stull

supports the waste material in the level.

Fig. 25 shows a stone arch when one wall of the formation requires support.

Fig. 26 illustrates a passage lined by a combination of stone or brick walls

with wooden caps and lagging for the roof.

Fig. 27 illustrates the lining of a drift or level supported by means of iron or steel shapes bent into the form of an arch and employed for the support of lagging.

Fig. 28 illustrates a cast-iron post or stull that has been successfully used

Fig. 28 illustrates a cast-iron post or stull that has been successfully used as a support in mines. It is composed of two pieces a and b, held together by a collar c. By driving c down on the post, the two pieces can be taken

apart and the post moved.

Fig. 29 illustrates a masonry shaft lining supported by means of cast-iron plates C set in bell-shaped cavities cut in the walls of the shaft. As the masonry of a section from below is built up toward that above, the overhanging portion D is cut out a little at a time, and the masonry from below built up under the plate so that the lining becomes continuous.

Fig. 30 illustrates masonry shaft linings, supported by artificial stone or cement foundations built in bell-shaped cavities cut in the walls of the shaft. The blocks of artificial stone are provided with inclined bearings C, which serve to transmit a portion of the downward thrust of the lining in the

direction of the arrow.

Iron and Steel Supports.—The use of iron or steel, either for vertical or norizontal supports in mines, has not become at all general. In America, timber is as yet comparatively cheap in most mining localities, but this situation is fast changing and the timber reserves are being rapidly cut off, so that many mines now using wood must, in the comparatively near future, resort to some other form of support. Some of the disadvantages of metal supports are their greater initial cost, and on this account it is essential that all such supports should be recovered. As very little timber is recovered in American mining, this objection is one that will probably continue. The mine water is often of such a character that it will dissolve iron or steel: particularly is this the case in copper mines, and in any mines where there is much pyrites. Metal mines keep their shaft sets open but a short time compared with the pit bottoms of large coal mines, and hence the extra cost of metal construction is frequently not warranted. The districts in which metal mines are located are more likely to be disturbed than is the ground over a coal mine, and if timbering is crushed, it is much easier to repair than iron or steel. Another objection to metal supports is the fact that they cannot be as easily framed and worked as timber.

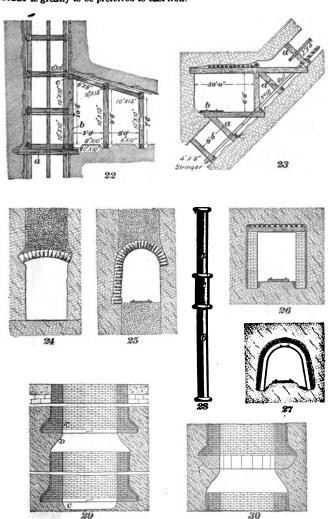
is the ground over a cost infine, and it imbering is custout, it is much cause to repair than iron or steel. Another objection to metal supports is the fact that they cannot be as easily framed and worked as timber.

On the other hand, the life of metal is, under ordinary circumstances, much greater than that of timber, and while the inital cost may be greater, whenever the metal can be recovered it can be used over and over again, and it always has a certain value as scrap iron or steel. After a metal beam has bent, it can still be used by simply turning it upside down. Another advantage for steel is that it occupies less space than timber or masonry, and thus gives a larger effective area of roadway for the same cost of driving.

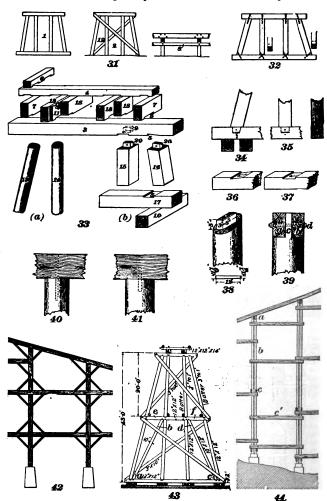
or else the amount of excavation may be reduced.

Although metal has not been greatly used for props or upright supports, it has been quite extensively used, both in America and abroad, for supporting shaft bottoms and landings, and in England it has been quite successfully used for cross-bars in timbering roads, the bar being set upon wooden legs. In some of the European mines, a complete metal casing has

been used. In locations where a constantly increasing pressure comes upon the roof, an elastic bending material must be used, and in such case, soft steel is greatly to be preferred to cast iron.



Trestles.—Figs. 31 and 33 illustrate the various timbers and methods of cutting the joints for ordinary railroad trestles. In Fig. 33 the portion (a) at the left illustrates the manner of framing a pile trestle, while the portion (b) at the right represents the manner of placing timbers and cutting the joint for the framed trestle. Fig. 31 represents bents of a frame and pile trestle



and the side elevation of a low pile trestle. The various pieces in the figures re numbered, and the accompanying table gives the names of the parts.

Packing Block, 11.
Packing Bolts, 12.
Piles, Batter, Inclined, Brace, 15.
Vertical, Plumb, Upright, 14.
Posts, Vertical, Plumb, Upright, 15.
Batter, Inclined, 16. Bent, Framed, 1. Bent, Pile, 2. Cap, 3. Cross-Tie, 4. Dapping, 5. Gaining, see Dapping, 5. Guard-Rail, 6. Sill, 17. Jack-Stringer, 7.
Longitudinal Brace, 8. Stringer, 18. Sway-Brace, 19. Mortise, 9. Tenon, 20 Mud Sill, 10. Waling Strip, see Longitudinal

Notching, Gaining, Dapping, 5. Brace, 8. Fig. 32 illustrates a bent of a frame trestle that is fastened together entirely

by means of drift bolts, no joints whatever being cut. Figs. 34 and 35 illustrate one manner of cutting the tenons and mortises on the ends of the batter braces and posts and frame bents, and also the drain holes that are bored in the mortise to prevent the timber from rotting. Usually the sills are notched or boxed to receive the ends of the timbers, in addition to having mortises formed in them. Figs. 36 and 37 show such joints for

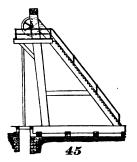
receiving the batter brace and post.

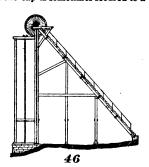
Fig. 38 illustrates the manner in which a tenon is sometimes formed on the top of the pile to secure the cap. When the cap is secured by a tenon. the two are united by a wooden pin shown in the lower part of the figure,

and known as a treenail.

Fig. 39 illustrates a manner in which the cap may be placed upon a pile trestle by splitting the cap into two pieces, a and b with the tenon c the full width of the pile between them.

Fig. 40 illustrates the manner in which the cap is sometimes secured to a





pile by means of a drift bolt, and Fig. 41 shows the manner in which the same thing may be accomplished with the use of a dowel.

Figs. 42 and 44 show two methods of longitudinal bracing between the bents of the trestles for inclined planes, such as are used at breakers or concentrating mills.

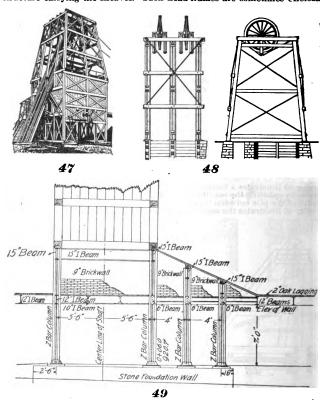
Fig. 43 is an elevation of a high trestle, showing the cross-bracing and

framing of the structure.

Timber Head-Frames or Head-Gears.-Fig. 45 is the simplest form of headgear, which consists of a vertical post to carry the weight of the sheave, etc., and a diagonal post that approximately bisects the angle between the rope from the drum and the rope hanging down the shaft, thus taking the resultant pull upon the axle of the sheave. There is usually some extra timbering, as shown, to support the cage guides and form a platform about the sheave for convenience in oiling.

Fig. 46 shows a modified form of the same type of frame, in which the main upright leg is vertical and in which there is also another vertical member on the opposite side of the shaft. The inclined leg is also brace and connected to the main vertical member.

Fig. 47 is a head-frame for an inclined shaft where the ore pocket is in th structure carrying the sheaves. Such head-frames are sometimes enclose



in their upper portions in a building so as to protect the men during winter. Fig. 48 is a form of framing quite common in the anthracite coal fields of Pennsylvania, in which the timbers are further braced by tie-rods, as shown.

Steel Shaft Bottoms.—Fig. 49 is a shaft bottom fitted with steel supports.

the posts being Z-bar columns and the caps being replaced by I beams, the posts being **Z**-bar columns and the caps being replaced by **I** beams, which, in the station proper, are supported on stone or brick walls. This metal construction is employed throughout all the portion of the bottom landing and passages where the cars are handled after they are brought from the workings or before they are returned to the workings.

Undersetting of Props.—The following table, from Sawyer's "Accidents in Mines." gives the maximum and minimum angles at which props should be set for varying inclinations. This table can be taken as a general guide, but it does not take account of the length of prop nor the varying amounts of movement of the top rock under different conditions.

of movement of the top rock under different conditions.

UNDERSETTING OF PROPS.

Rate of Inclination of	Angle or Unde	erset of Props.
Seam. Degrees.	Minimum Degrees.	Maximum Degrees.
6 12	0	1 2
. 18 24 30 36	1 1 2	3 4 5
42 48	2 3	7 8

METHODS OF WORKING.

3

No definite rules can be given for the selection of a method of mining that will cover all the conditions that may exist at any given mine. Each mine is a distinct and separate proposition, and each superintendent must judge how he will adapt the general principles here given to the local conditions at his own mine. Every system of mining aims to extract the maximum amount of the deposit in the best marketable shape and at a minimum cost and danger.

OPEN WORK.

Open work applies to the working of all deposits that have no overburden, or to those in which the overburden or overlying material is stripped from the portion of the deposit to be removed by hand, steam shovels, scrapers, etc. It includes particularly all quarries and placer workings, and can be

applied to many mineral and coal deposits.

The advantages of this system are that no timber is required; unprofitable underground workings do not have to be kept open and in repair; when required, a simple hoisting plant is used; there is less danger to the work-men from falls of roof and from blasting: there is practically no danger from first artificial lights are not required; mining can be done more economically, as larger faces are open, larger blasts can be used, and the amount of work accomplished per miner is greater, and better superintendence can be had; the health of the men is usually much better when working in the open; the deposits can be more easily extracted and the ore more easily and more perfectly selected, and, under proper conditions, the output can be increased almost indefinitely.

The disadvantages of open work are: A large amount of overburden often has to be removed and a place for sorting this waste material provided; the workmen are exposed to the weather; the expense of open work increases

54 and upwards

rapidly with depth of covering.

Open work may be divided into two general classes: First, where the whole or a greater part of the deposit is of value and has to be removed, as in quarries and in ordinary mines; second, where the valuable portion is but a small part of the whole, as in placers or fragmental deposits carrying gold,

platinum, etc.

Deposits of the first class may be worked as follows: (a) The deposit is stripped, if necessary, and the material is removed by hoisting with derricks or a cableway, or by drawing out in cars with the use of underground passages. This class includes practically all quarries for building or ornamental stone, slate quarries, and most of the open-pit and steam-shovel iron, phosphate, and similar mines. (b) The deposit is stripped, and drifts or tunnels are extended through the material below the surface, either from adjacent valleys or from shafts sunk outside of the deposit. The material,

after being mined in the open pit, is thrown through openings to these drifts or tunnels, through which it is trammed to the surface or to the foot of the

hoisting shaft.

Steam-shovel mines are those in which the material is, when necessary, first shaken loose by big blasts of low-grade powder, and then loaded into railroad cars with steam shovels, which lift the ore from its natural bed and deposit it in cars to be taken directly to market or to a concentrating or washing plant. Mining is thus done very cheaply, but the steam shovel, from a mechanical standpoint, is not an economical machine and the costs of repairs are high. The expense for hauling material from the steam shovel increases rapidly with adverse grades. Economy in steam-shovel mining depends on the shovel being kept constantly at work. An output of 2,000 tons per day for a steam shovel and one locomotive has been reached and even surpassed, but this cannot be taken as an average for a season's work. Under favorable conditions, there is probably no cheaper method of mining. The cost of removing 97,854 yd. of material over a seam of anthracite coal was \$1 per ton of material stripped, and \$0.516 per ton of coal obtained. The average depth of the stripping was 75 ft. and about two-thirds of the material removed was rock. The cost of stripping a bank 15 to 18 ft. high in Western Pennsylvania was \$0.30 per cu. yd. of stripping.

By milling system, the deposit is stripped, shafts are sunk outside of the boundaries, and drifts are extended through the ore some distance from the surfice. From these drifts raises are not up to serve as chutes after

By milling system, the deposit is stripped, shafts are sunk outside of the boundaries, and drifts are extended through the ore some distance from the surface. From these drifts, raises are put up to serve as chutes, after which the material is simply blasted loose and worked into these raises, through which it passes to the underground passages, and is trammed to the shafts and hoisted to the surface. The advantages of this system over the steam-shovel methods are: It is not necessary to make any long cut through the overburden to bring the cars on the surface of the ore body. The mining force can be employed underground in extending drifts and driving new raises in bad or stormy weather. Very little handling of the material by manual labor is required, the men simply working the loosened ore into the chutes by means of bars or shovels, without having to lift any of it.

Cableways in Mining.—Cableways are extensively used for stripping deposits, for transporting material after it has been quarried, and also for mining soft or loose deposits, such as clays, phosphates, and gravels. The cost of removing the overburden varies greatly with the nature of the ground, and depends largely on the distance to which it is necessary to carry the waste material before dumping. Frequently, a cableway can be installed spanning both the place of mining and the dumping ground. In other cases, one end of the cableway is fixed and attached to a washing or gold-saving plant, while the other end revolves about this fixed point in a circle until all of the material within this circumference has been excavated; the entire plant is then moved to another location. The advantages of cableways over steam shovels or dredges are that the load may be delivered at a considerable distance from the point of excavation, while the entire apparatus rests on banks entirely clear of the excavation.

Cableways have been constructed with single spans up to 1,650 ft., handling 25-ton loads, and delivering an average daily capacity (10 hours) of 617 yd. of rock. Mr. Spencer Miller places the following limitations on the practical applications of cableways: Span (single), 2,000 ft.; load, 25 tons; speed of travel, 1,800 ft. per minute; speed of hoist, 900 ft. per minute. The average practice, however, is about as follows: Span, 600 to 1,200 ft.; loads, 3 to 7 tons, speed of travel, 500 to 1,000 ft. per minute; speed of hoist, 150 to

300 ft. per minute.

Placer or fragmental deposits may be worked by means of a stream of water from a pipe or nozzle directed against the bank (hydraulic mining), or the material may be excavated by hand or by mechanical means, such as

dredges, steam shovels, etc.

Hydraulic Placer Mines.—The material is broken down by water flowing over the bank, as flume waterfalls, or along the ground so as to ground-sluice the material. The material is frequently just loosened by means of picks or shovels, the current being depended on to carry it away. This is commonly called ground skuicing. Another method of excavating the material is odirect a stream of water against the bank from a pipe or nozzle. This is true hydraulicking. After the material has been loosened by the water, it is allowed to flow through sluices and over undercurrents or gold-saving tables so as to recover the valuable portions.

Placer Mines Worked by Mechanical Means.-Where water is scarce, the material may be excavated by steam shovels or other excavators, such as grab, or scooping, buckets, operated by cableways. The material is then washed by a limited supply of water that is frequently used over and over, or it may be passed over a dry washer or concentrator. Both the steam shovel and the cable excavator have proved very efficient means for working certain classes of deposits.

Dredge Mining.—Where the gold-bearing material lies below the water level, or where water can be introduced so as to float a boat, a dredge may

be employed.

For gold dredging, a dredge should fulfil the following conditions: (1) Speed and readiness in moving and taking up different positions; (2) an adaptability for cleaning up rock, and for digging to a maximum depth; (3) feasibility of working and of the banking or disposing of the tailings; (4) cheapness in working, as most of the dredging propositions are of

low grade.
Three types of dredges have been used: the hydraulic suction dredge, the shovel dredge, and the continuous-bucket ladder dredge. The first of these is well adapted for digging very small gravel and sand, but is not suited for boulders or even large stones without a great loss of efficiency. The continuous-bucket dredge has proved the most successful under ordinary circumstances, as it is controlled by lines and not by spiles or spuds, and hence can be shifted more rapidly and made to conform to irregularities in the bed rock more readily than the dipper type. Also, the continuous-bucket dredge furnishes a constant supply of material to the apparatus used for

recovering the gold.

A continuous-bucket dredge can operate to a depth of 60 ft. According to Mr. R. H. Postlethwaite, of San Francisco, Cal., a decided advocate of continuous-bucket dredges, the cost of working a shovel dredge runs from 7 cents per cubic yard upwards; but he claims that the bucket dredge can be worked at a cost of from 3 to 5 cents per cubic yard, including a charge of \$100 per week for depreciation. The cost of running a small gold dredger should not average over \$200 per week—that is allowing \$125 for wages, \$50 for fuel, and \$25 for repairs, etc. If the dredger handles 10,000 cu. yd. per week—that twould be at a cost of 2 cents per cubic yard. If the material week, that would be at a cost of 2 cents per cubic yard. If the material averaged 6 cents per cubic yard, there should be an approximate profit of \$400 per week on an investment of from \$25,000 to \$40,000. 18 cu. ft. of gravel in place will weigh 2,000 lb.; a cubic yard will weigh 14 short tons.

CLOSED WORK.

Under this general heading it is customary to divide the methods of mining into coal-mining methods and metal-mining methods. This classification is not entirely logical, for identical methods are applied to flat bedded deposits of coal iron ore, clay, salt, etc., and identical or very similar methods to highly inclined coal seams and mineral veins. A more logical classification is one based on the position, character, and thickness of the deposit, but the older classification has become so firmly established that it

is not advisable to give it up entirely in a pocketbook.

Bedded Deposits. -The typical and most extensive bedded mineral deposits are of coal and iron ore, and of these the former is by far the more extensively A description of the several methods of mining coal beds will therefore comprise not only all of the essential points in the mining of other bedded deposits, but will include a number of points not usually considered in mining such deposits. The chief of these is the presence of explosive gas in such quantities as to influence the choice of a method of mining. From the descriptions of the methods of coal mining here given it will therefore be a comparatively simple matter for the miner of clay, iron ore, etc. to adapt a method.

COAL MINING.

Ceneral Considerations.-The elementary causes affecting the extraction of coal are (1) weight of overlying strata or depth of the deposit; (2) strength and character of roof; (3) character of floor; (4) texture of bedded material; (5) inclination and thickness of bed; (6) presence of gas in the seam or in adjoining strata.

Roof Pressure.—Of these causes, the roof pressure is the most important, and a number of the other causes are directly affected by it. The weight of the overlying cover will give a maximum roof pressure, but this may be so variously modified that the determination of the actual pressure is practically impossible, and estimates of this pressure must be based largely on practical experience; hence, rules for its calculation are of comparatively little value. One very essential point, however, must be borne in mind, i. e., that the direction of pressure is perpendicular to the bedding plan.

Strength and Character of Roof.—The strength of roof refers to the power of

being self-supporting over smaller or larger areas. A strong roof permits larger openings, but increases the load on the pillars, thereby necessitating A weak roof requires smaller openings, and permits smaller pillars when the floor is good. A strong roof may yield and settle gradually, giving good conditions for longwall work, or it may be hard and brittle, and difficult to manage.

The character of floor influences largely the size of pillars. A soft bottom requires large pillars and narrow openings, especially when the roof is strong.

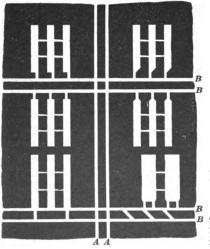
Texture of Coal and Inclination and Thickness of Seam.—Soft, friable coal requires large pillars, while a hard, compact coal requires only small pillars. The inclination and thickness of the deposit increase the size of pillars required, and also influence the haulage, drainage, timbering, method of

working, arrangement of breasts, etc.

The presence of gas in the seam or in the enclosing strata affects the system of working, as ample air passages must be provided, and provision must frequently be made for ventilating separately the different sections of the mine. Where the gas pressure is strong, and outbursts are of frequent occurrence, narrow openings are necessitated that render the workings safe until the gas has escaped.

SYSTEMS OF WORKING COAL.

There are two general systems of working coal seams: (1) room-and-pillar,



room-and-pillar workings become impracticable when the thickness of the pillars necessary to support the roof pressure much exceeds double the width of the breast openings.

and (2) longwall. are, however, a great num-ber of modifications of each, and it is often difficult to exactly classify a given method under either of these two systems.

The room and pillar system, also known as the pillar-and-chamber or bordand-pillar, and which may include the pillar-and-stall, system, is the oldest of the systems, and the one very generally used in the mines of the United States. this system, coal is first mined from a number of comparatively small places called rooms, chambers, stalls, bords, etc., which are driven either square from or at an angle to the haulageway. These openings may be wide or narrow. and may be either a roadway, incline, or chute, according to existing conditions. The pillars that are left between the openings in the original workings support the roof, and are usually subsequently All forms of removed.

The piller-and-stall system is similar to the room-and-pillar system, but in the former the stalls are opened off from the entry their full width, while in the latter the rooms or chambers are turned narrow, and widened inside to their regular width. Fig. 1 shows a typical room-and-pillar method for working an approximately horizontal seam of coal of moderate thickness (4 to 10 ft.), and with a fairly good roof and bottom. Main headings A are usually driven perpendicular to the strike, unless this direction is changed by the cleat in the coal, as explained later. Cross-headings, or entries B, B, are turned off at regular intervals, and at an angle of 90° to these main headings, the distance between any two pairs of cross-entries being determined, in flat seams, by twice the length to which a room can be driven which in turn is determined by the character of the roof, floor, and seam. The rooms are turned to the right and left of each pair of but headings, and driven until they meet, or one-half the distance between two pairs of entries. After the rooms are driven up, the pillars between the rooms are drawn, and later the room stumps along these entries, and the entry pillars themselves, are drawn, unless it should be necessary to keep some of these cross-entries open for purposes of ventilation. A large chain pillar is left to protect the main headings.

When cross-entries have been extended a considerable distance, roads are often driven between them parallel to the main heading A. The object of these subroads is to reduce to a minimum the air-courses and roadways to be maintained; or such a subroad may be necessary on account of a squeeze crossing any pair of cross-entries. The extent of the territory worked out to the right and left of each main entry is a matter for local determination.

The room openings are made suitable to prevailing conditions, and Fig. 1 shows several of the common methods. The width of the room and the form of the opening depend on the character of the roof and the extent to which it is necessary to leave a pillar to support the cross-heading, it being advantageous, of course, to open out the room to its full width at the earliest

possible moment.

Longwall Method of Mining.—The longwall system contemplates the extraction of the entire seam or bed, and the original significance of the term "longwall" was a continuous line of breast. No portion of the seam is allowed to remain after leaving the vicinity of the shaft. The method depends on producing a uniform and gradual settlement of the roof a few yards behind the working face. Pack walls are built on each side of the roadways, and at regular intervals in the gob or waste area, and the roof settles firmly on these packs, pressing them into the bottom, or compressing them until the roof subsidence is complete. The height of the main roadway is maintained by "brushing" the roof or lifting the bottom. Longwall may be advancing or retreating. In longwall advancing, mining begins at onear the foot of the shaft and advances outwards, forming a gradually widening and increasing length of face to the boundary. The passages are made through the excavated portions of the mine, and are maintained by pack walls built either of the refuse secured in mining or sometimes from material brought in from the surface. In longwall retreating or withdrawing, entries, gangways, or headings are first driven to the boundary or to other convenient distances inbye, and the pillars between these entries are then drawn back toward the shaft; this is also called working home.

Fig. 2 shows a plan of combined longwall advancing and retreating. In

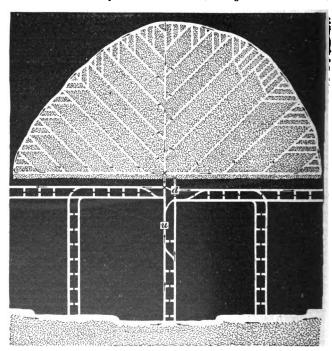
Fig. 2 shows a plan of combined longwall advancing and retreating. In the upper arrangement, or Scotch longwall, the face is semicircular and the roads are turned off at angles of 45°. This plan is suitable for seams up to 3 ft. thick with a weak top, and which pitch less than 20°, and situated at almost any depth. It is the one from which most of the longwall practice in the central coal basins of the United States is taken. In the lower portion, which shows one method of longwall retreating, narrow parallel headings are driven in pairs to the boundary, being from 200 to 300 ft. apart. Such a combination of longwall advancing and retreating insures an unvarying supply of coal, for while one side continually leaves the shaft, the

other approaches it.

Longwall is specially adapted to flat seams or those having a regular and moderate pitch, and which are free from faults; to hard rather than to soft coal; and to the use of undercutting machines. It is also easy of ventilation and economical in timber, explosives and track.

In all longwall work, the weight of the roof is made to act upon the coal face, which is undercut, according to the ability of the miner and the conditions of the seam, from 2½ to 3 ft. deep. This weighing action of the roof

performs the work of the powder and breaks the coal in a few hours or less after the sprags have been removed. The time required to break the coal will be greater or less, according to conditions. The success of the entire system, as will be readily seen, depends on a uniformly regular advance of system, as will be readily seen, depends on a dimonny regular advances the line of the face or breast, and a uniform system of setting and fawing timber at the face; also, uniformity in the pack walls along the roads, and in the amount of gob packing. This system does not permit of long idle spells induced by strikes or other causes. The coal does not break well, either, when some of the men are out a portion of the time, and their places lie idle. The life of the whole system consists in maintaining what miners call a



F1G. 2.

traveling weight upon the coal face, which can only be accomplished satisfactorily by uniformity in every part of the work.

Longwall advancing is better suited to thin seams than to thick ones, to

Longwall advancing is better suited to thin seams than to thick ones, to flat rather than pitching, and to good roofs and hard floors.

Longwall retreating is better adapted to thicker beds; to those liable to gob fires; to seams of hard coal having a considerable pitch; to pockety, or irregular seams: and to a soft and treacherous top. The air-course is also less broken along the face, and better haulage installations can be made. Its chief disadvantage is the large amount of dead work necessitated before returns are received. With this system there is no expense in keeping up the haulage road so far as creep or falling roof is concerned, as the roads are all in solid coal nor is there any trouble from con fires or water and little all in solid coal, nor is there any trouble from gob fires or water; and little

detriment to the working face is caused by the mine having to stand idle for a time. If the seam is high enough for the mules or horses, no rock whatever will need to be taken down. The coal seam will be proved before 10% of it is extracted.

The ventilation in the retreating plan is as near perfect as it is possible to get it in practice. All the airways are tight, a thing impossible to get in the advancing plan; and it is a comparatively easy matter to shut off fire or to

allow a portion of the working face to remain idle.

Longwall retreating is frequently used for working quite limited sections of a mine in which the seam of coal is 16 to 20 ft. thick, and inclined not more than 10°. A series of 8 or 10 pairs of headings are turned off the butt entry and driven a distance, dependent on local conditions, where the working face is formed by driving cross-cuts from one to the other. This face is carried back on the retreating plan, allowing the roof to cave in or settle on the gob as the work approaches the butt entry. In this way, any extra weight that would crush and ruin the adjacent coal is sovided. This method is also used in lower seams in which the coal is soft, or the roof, or bottom, or both, are of such a nature as to give trouble in working the room-and-pillar system. Sometimes, instead of driving pairs of headings at considerable distances apart, a number of single headings are driven comparatively close together, and connected by cross-cuts from 10 to 20 yd. apart. When the limit of the section is reached, the working face is formed and carried back, as in the other plan. This latter method is more suitable for tender roof, or a coal in which the face and butt cleats are not prominent.

Starting longwall.—There are two methods of starting longwall workings. In the first, the work of extraction begins at the shaft itself, the coal being taken out all around and its place filled with solid packs, leaving only space for the roadways. In the second method, a pillar of solid coal is left to support the shaft, cut only by the roadways. The longwall work is then started uniformly all around this pillar. Great care is needed in building the first pack walls around the shaft pillar, to see that they are solidly built and well rammed, in order to break the roof over the coal. The system will not work rightly, however, until the breast has been advanced some distance from the pillar, so as to secure the benefit from the weighing action of the roof upon the coal face. The mining will be more difficult in the start, and in some exceptional cases it may even be necessary to place some light

shots; which, however, should be avoided, if possible.

The panel system divides a mine into districts or panels by driving entries and cross-entries so as to intersect one another at regular intervals of, usually, about 100 yd. Large pillars are left surrounding the workings within each panel, and any method of development may be used for each panel. This system presents the following advantages: (1) Better control of the ventilation, since the air in any panel may be temporarily increased or decreased as required. An explosion occurring in one panel is less liable to affect the other workings. (2) Coal may be extracted, pillars drawn, and the panels closed and sealed off independently of each other. (3) Greater security affords against creep and squeeze. (4) Coal that disintegrates on standing

can be quickly worked out.

Bearing In, or Undercutting.—In any method of mining where the coal is undermined, advantage should be taken of the roof pressure to assist in both breaking down the coal and also in bearing in. The fact is often overlooked that the roof pressure upon the face coal makes it brittle and more susceptible to the pick, and the good miner starts a shallow mining in the under clay, or lower coal, and carries it the entire width of the face. By the time he returns to the side of the breast at which he started, the roof pressure has made the coal more tender and susceptible to the pick. Such a gradual system of mining throws the pressure on the coal face gradually, and the coal breaks in larger pieces. The depth of the undercut depends on the thickness of the seam and the other conditions. Undercutting by mining machines is rapidly replacing hand work wherever these machines can be used.

Buildings, Pack Walls, and Stowing.—Pack walls should be built large enough at first and kept well up to the face, to prevent the weight coming upon the timber and also to permit the roof to settle rapidly when the timber is taken out of the face. Often the roof will not stand this second movement without breaking, and possibly closing in the entire face. The face should therefore be kept in shape, and just as soon as there is room for a prop or

chock, it should be put in immediately, and the pack walls likewise sho

be extended after each cut or web is loaded out.

As a general thing, the pack walls in the gob are not so wide as the reside ones, particularly when the seam produces enough waste mate to stow the "marches," "cundles," or "gobs," between these pack wall usually about 50% of the cubical contents of the solid seam taken out stow the spaces between the pack walls in thick pitching seams, where entire gob must be completely filled or nearly so. No waste material, exc such as will hasten spontaneous combustion, should be taken out of mine to the surface.

mine to the surface.

Timbering a Longwall Face.—The method of timbering the working f depends on the nature of the roof, floor, coal, etc. The action of the roof the coal face is regulated almost entirely by timber; consequently, when coal is of such a nature as to require little weight to make it mine easily, roof must be timbered with rows of chocks and, if necessary, a few pro Control of Roof Pressure.—The working face of a longwall working sho advance up grade, but this face cannot always be kept parallel with strike. When the angle at the line of face, made with the line of strike less than 90°, the greater pressure of the covering rocks is thrown on gob, and, when this angle is more than 90°, the greater pressure comes the coal. The angle made by the working face with the line of pitch vai inversely as the vertical angle of pitch, or for a high pitch this angle small and for a low pitch it is large. Where longwall is worked in adjacesections, care must be taken to prevent the advancing of one section three. sections, care must be taken to prevent the advancing of one section throing a crushing weight on any of the others, and thus producing a crush an uncontrollable cave. Where the rocks are pitching, and a greater port of the cracks that cut them run in lines parallel to the strike, neither sto nor timber can efficiently support the roof, which frequently breaks off cl to the working face.

The ends of all stone packs nearest the face of the coal should be in li and the ends of these pack walls should form a line parallel to the face



the coal. Timbers set at equal distances and line along a longwall face are much more efficie in supporting the roof than irregularly set ti Fig. 3 shows the proper way of locati bers. the pack walls and the face timber.

Number of Entries.—The entries in a mine m

be driven single, double, triple, etc. The single-entry system is only advisable und certain conditions and for short distances, sir the ventilation must be maintained along t face of the rooms, and there is but one haula way, which may easily be closed by a fall or creep. Rooms are turned

one or both sides of the entry. The double-entry system is most commonly used. Two parallel entr are driven, separated by an entry pillar whose thickness varies with t depth of the seam, and connected at intervals of about 20 yd. by cross-cu

or breakthroughs to maintain ventilation.

The triple-entry system is used particularly in very gaseous seams requing separate return airways; or, at times, in mines where the large outrequires ample haulage roads. It is usually applied to the main entries on but sometimes, also, to the cross-entries. In gaseous mines, the mide entry is usually made the haulage road and intake airway, and the outsi

entry is usually made the nathage road and intake airway, and the outs entries the return air-courses for either side of the mine, respectively.

A still larger number of entries even has been suggested for de workings where it is difficult to keep open broad passages, but these ha not been generally adopted or tried experimentally to any great externain headings and the rooms driven parallel to the direction of the dip, a the cross-headings parallel to the strike, but in most coal seams there a vertical eleavages called clear which pross the coal in two directions she vertical cleavages, called cleats, which cross the coal in two directions about at right angles to each other. Face cleats, as they are called, are the morpronounced, while the end or butt cleats are the shorter, less pronounce joints. The direction of the face with respect to the cleats is of principles. importance as greatly facilitating or retarding the mining of the coal.

Fig. 4 shows the different positions that the face may occupy with respect to the direction of the cleats. The angle of the breast depends on the had ness of the coal and freedom of the cleats, and each method has its peculi PILLARS. 28

adaptation to the varying conditions of a coal seam. When the face cleats are working free and the coal is very soft, it may be necessary to drive "end On." The end-on method is best adapted to a very heavy roof pressure, while for a light roof pressure the short-horn method assists in breaking the coal. If the "face" cleats are free and the coal breaks readily along them, and it is reasonably hard, the long-horn method is adopted, for when the coal is undercut it needs more support than it gets from the cleats, and its weight must be thrown somewhat upon the end cleats. "Face on" is adopted when the face cleats are not as free or numerous as the butt cleats.

Unless the coal at the face receives sufficient support, the undercutting or bearing in cannot be thoroughly done, or else the amount of spragging and the risk to the miner are increased. When the end cleats are less pronounced and numerous, and the roof pressure great, the coal will probably break better by carrying wide breasts upon the ends of the coal, and it is then an advantage to drive double rooms with

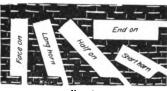


Fig. 4.

large pillars between them. In pitching seams, the pillar should have very long sides perpendicular to the strike, if the principal cleats in the coal

are parallel to the strike, or nearly so.

The short-horn method is adapted to heavy roof pressure and wide room pillars, as the face cleats are here quite pronounced, and the pillars between the rooms thereby weakened to a large extent; hence, wide pillars are more often employed when working on the ends of the coal. When the face cleats are less pronounced, and the end cleats are working freely, a good breast of coal is carried on the face, and, unless other conditions require it a great width of room pillars is not needed. If this can be done consistently, and good lump coal secured at the same time, the room should cross the pitch as little as possible, as a side pressure upon the pillars having very long sides running diagonally across the pitch is destructive.

PILLARS.

Size of Pillars.—It is impossible to give exact rules or formulas for determining the proper size of pillars. Each case in practice requires special consideration, and in laying out the pillars in a virgin field it is well to find out what the current practice is in similar fields. In general, the thickness and the greater its depth from the surface, the greater should be the thickness of the pillar. Some coal deteriorates rapidly when subject to weight and to the disintegrating effect of the atmosphere, and pillars of such coal must be larger than when composed of a hard compact coal. Permanent pillars, or those that are to remain for a considerable length of time, must be larger than those that are to be promptly removed. Pillars about the bottom of a shaft, or along main haulage roads, should be left large enough to provide for increasing developments, for when landings are enlarged or when haulage systems are introduced, the original pillars frequently have to be reduced in size by taking a skip off of them or by taking out chambers for engines and pumps.

Shaft Pillars.—Various formulas have been given to determine the size of shaft pillars, and the results given by these several formulas are very diverse.

Merivale.— $S = \sqrt{\frac{D}{50}} \times 22$, where S equals the length of the side of the pillar in yards, and D equals depth of shaft in fathoms.

Andre.—Up to 150 yd. depth, have the pillar 35 yd. square, and for greater depths increase 5 yd. on each side for every 25 yd. of increased depth.

Oren.—Draw lines enclosing all surface buildings that it is necessary to erect about the head of the shaft, and make the shaft pillar so that solid coal will be left outside these lines all around for a distance equal to one-third the depth of the shaft.

Wardle.—Shaft pillars should not be less than 40 yd. square down to a

Wardle.—Shaft pillars should not be less than 40 yd. square down to a dethor of 60 fathoms, and should increase 10 yd. on a side for every 20 dethors increase in doubt.

fathoms increase in depth.

Hughes.—Leave 1 yd. in width of pillar for every yard in depth of shaft.

Pemely.—Allow a pillar 40 yd. square for any depth up to 100 yd.; for greater depths, increase the pillar 5 yd. for every 20 yd. in depth.

Calculating the size of pillar from each of these authorities, we find the

following variations:

Authority.	For Shaft 300 Ft. Deep.	For Shaft 600 Ft. Deep.
Merivale Andre Wardle Pamely Dron Hughes	22 yd. square. 35 yd. square. 40 yd. square. 40 yd. square. 33‡ yd. square.* 100 yd. diameter.	31 yd. square. 45 yd. square. 60 yd. square. 65 yd. square. 66 yd. square.* 200 yd. diameter.

"Outside of buildings.

None of these formulas takes account of the thickness of the seam, and the following formula, which takes account of this very important element, was suggested by Mr. R. J. Foster, in "Mines and Minerals":

Radius of pillar = $3\sqrt{D} \times t$, in which D = depth of shaft; t = thickness of seam.

Pitching seams require smaller pillars on the low side than on the rising side of the shaft.

Room Pillars.—The relative width of pillar and breast is dependent on the weight of cover, as compared with the character of the roof and floor and the crushing strength of the coal. These relative widths are determined largely by practice. Speaking generally, the narrower the rooms or chambers, the higher the cost in yardage, the greater the production of slack and nut coal, the greater the consumption of powder, track iron, ties, etc., and the greater the cost of dead work.

For bituminous coal of medium hardness and good roof and floor, a rule often used is to make the thickness of room pillars equal to 1% of the depth of cover for each foot of thickness of the seam, according to the expression $W_p = \frac{t}{100} \times D$, in which $W_p = \text{pillar}$ width; t = thickness of

seam; D= depth of cover, and then make the width of breast or opening equal to the depth of cover divided by the width of pillar thus found, according to the expression $W_o=\frac{D}{W_o}$, where $W_o=$ width of room.

Frail coal and coal that disintegrates readily when exposed to the air, and a soft bottom, may increase the width of pillar required as much as 50% of the amount found above; also, a hard roof may increase the same as much as 25%, while on the other hand, a frail roof or a hard coal or floor may reduce the width of pillar required 25%. The hardness of the roof affects both the width of pillar and width of opening alike, which is not the case with any of the other factors.

DUNN'S TABLES OF SIZE OF ROOM PILLARS FOR VARIOUS DEPTHS.

The following table is for first working, with the design of afterwards taking out the pillars, the width of the principal workings being 5 yd., and cross-holings 2 yd.

Depth. Feet.	Size of Pillars. Yards.	Proportion in Pillars.	Depth. Feet.	Size of Pillars. Yards.	Proportion in Pillars.
120 240 360 480 600 720 840 960	$\begin{array}{c} 20 \times 5 \\ 20 \times 6 \\ 22 \times 7 \\ 22 \times 8 \\ 22 \times 9 \\ 22 \times 12 \\ 26 \times 15 \\ 28 \times 16 \end{array}$.41 .50 .52 .57 .59 .61 .63	1,080 1,200 1,320 1,440 1,560 1,680 1,800	$\begin{array}{c} 26 \times 14 \\ 26 \times 16 \\ 28 \times 18 \\ 28 \times 20 \\ 30 \times 21 \\ 30 \times 224 \\ 30 \times 24 \end{array}$.69 .71 .73 .75 .77 .78 .79

Extremely large pillars must often be left as a precautionary measure to protect permanent haulageways and surface buildings, or to avoid any possibility of a break in the roof that would cause an inflow of water.

TABLE SHOWING DISTANCE FROM CENTER TO CENTER OF BREASTS OR CHAMBERS MEASURED ON THE ENTRY OR GANGWAY, FOR DIFFERENT ANGLES.

Angle Be- ween Cham- ber and En- ry. Degrees.	D	istanc	е Ме		on that + V					n Wi	dth o	ſ
Angl tween ber an	20	25	30	35	40	45	50	55	60	65	70	75
90	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0
85	20.0	25.1	30.1	35.1	40.2	45.2	50.1	55.2	60.2	65.3	70.3	75.3
80	20.3	25.4	30.5	35.5	40.6	45.7	50.6	55.8	60.9	66.0	71.1	76.2
75	20.7	25.9	31.1	36.2	41.4	46.6	51.2	56.9	62.1	67.3	72.5	77.7
70	21.2	26.6	31.9	37.2	42.6	47.9	53.1	58.5	63.9	69.2	74.5	79.8
65	22.0	27.6	33.1	38.6	44.1	49.6	55.1	60.7	66.2	71.7	77.2	82.8
60	23.0		34.6	40.4	46.2	52.0	57.6	63.5	69.3	75.1	80.8	86.6
55	24.4		36.6	42.7	48.8	54.9	60.9	67.1	73.3	79.4	85.5	91.6
50	25.8				52.2	58.7	65.1	71.8	78.3	84.9	91.4	97.9
45	28.2		42.4	49.5	56.6	63.6	70.6	77.8	84.9	91.9	99.0	106.1
40	31.1		46.7	54.5	62.2	70.0	77.6	85.6	93.4	101.2		116.7
35	34.9		52.3	61.0	69.7	78.5	87.0	95.9		113.4	122.1	130.8
30	40.0	50. 0	60.0	70.0	80.0	90.0	100.0	110.0		130.0	140.0	150.0
25	47.3	59.2	71.0	82.8	94.6	106.5	118.1	127.2	142.0	153.8	165.7	177.5
20	58.5	73.1	87.7	102.4	117.0	131.6	145.9	160.8		190.1	204.7	219.3
15	77.4		115.9	135.3	154.5	173.9	192.8	21 2.5		251.2	270.5	289.8
10	115.2		172.8		230.4	259.2	287.3	316.7		874.4		432.0
5	229.5	286.9	844.2	401.6	459.0	516.3	572.5	631.1	688.5	745.8	803.2	860.5
			l	<u> </u>							1	

In the following table, the weight thrown upon pillars at different depths by the removal of different proportions of coal is given:

WEIGHT ON PILLARS IN POUNDS PER SQUARE INCH.

r of .	Percentage of Coal Left in Pillars.									
Depth (Seam Seam Feet.	90%	80%	70%	60≉	50%	40%	30%	20%	10%	
100 500 1,000 1,500 2,000 3,000 4,000 5,000 10,000	111 555 1,111 1,666 2,222 3,333 4,444 5,555 11,110	125 625 1,250 1,875 2,500 3,750 5,000 6,250 12,500	142 710 1,428 2,138 2,956 4,384 5,912 7,340	166 830 1,666 2,496 3,333 4,999 6,666	200 1,000 2,000 3,000 4,000 6,000 8,000	250 1,250 2,500 3,750 5,000 7,500	333 1,665 3,333 4,998 6,666	500 2,500 5,000 7,500	1,000 5,000 10,000 15,000	

Chain and barrier pillars vary in size even more than shaft pillars, and their widths are almost entirely determined by local considerations. In some States, the minimum width of barrier pillars is regulated by law.

Barrier Pillars.—For finding the width of barrier pillars in anthracite

Barler Pillars.—For finding the width of barrier pillars in anthracite seams, the following formula, adopted conjointly by the chief mining engineers of the Lehigh & Wilkes-Barre Coal Co., Susquehanna Coal Co., D., L. & W. R. R. Co., Delaware & Hudson Canal Co., and the State mine inspectors

Thus, for a seam 6 ft. thick, 400 ft. below drainage level, the barrier pillar should be $(6 \times 4) + (6 \times 5) = 54$ ft.

TABLE OF BARRIER PILLARS TO BE LEFT BETWEEN ADJOINING PROPERTIES.

DEPTH BELOW WATER LEVEL-ALL DIMENSIONS IN FEET.

ar.	009'1	8 8 9 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
pillar.	0971	888 222 222 222 24 4 4 4 4 4 4 4 4 4 4 4
ler	004,1	767 767 767 767 767 767 767 767 767 767
width of barrier	1,350	32 4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
J Jo	1,300	45278625555555555555555555555555555555555
th	1,250	85 5 8 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
wid	1,200	888 136 136 136 136 136 136 137 147 147 147 147 147 147 147 147 147 14
- 1	1,150	29885123223233333535353535353535353535353535
× 5)	001'1	\$288558465584465584685888866 \$48858888888888888888888888888888888888
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4 0	006	235528555555555555555555555555555555555
Sec	820	44884888888888888888888888888888888888
Dirith Below water level—All Dimensions in fert. $\times 1\%$ of depth below drainage level) $+$ (thickness of workings	008	88 93 93 93 93 93 93 93 93 93 93 93 93 93
th (th	094	88884488888888888888888888888888888888
	004	888 25 28 28 28 28 28 28 28 28 28 28 28 28 28
yel	099	8488824558355848688888888888
er-	009	84886888348448668 88843846
nag	999	822222 8222222222222222222222222222222
R I	909	8428588855884285588858888
ATE OW	420	25259 25259
bel	007	22678882128343351788882352383523835353
pth	320	. 8242687584855568788788788
de.	300	<u> </u>
% of	520	<u> </u>
X ×	200	288344885429885558884445885
ngs	120	82888888888888888888888888888888888888
rki	001	848844446844888448884481108844888448
f wc	09	72888342852588832851 12111111111111111111111111111111111
. SS 0.	. 0	12888834888855888888888888888888888888888
DLPTH DELOW WATER LEVEL—ALL FORMULA.—(Thickness of workings \times 15 of depth below drainage level)	Thickness Mined From Seam.	0.4100/0000 - M0.4100/0000 - M0.410
ĬΉ	l	04490000000000000000000000000000000000

Each adjoining owner is to leave one-half of the pillar thickness required.

Compressive Strength of Anthracite.—Attention has recently been called by Mr. William Griffith, of Scranton, Pa., to the advisability of testing the strength of the different coals and of using this data as a basis for the proper proportioning of the pillars and for determining the probability of a squeeze. In some crude experiments, which Mr. Griffith carried on, he found that different coals from even the same locality varied greatly in their strengths. If attention were given to this matter, probably the sizes of pillars could be calculated on a much more certain basis than is possible at present, and the liability to squeeze lessened.

The table on page 290 gives the results of some preliminary and crude tests made by Mr. Griffith, which supply the only data available as to the

crushing strength of anthracite coal.

Drawing pillars is about the most dangerous work the miner has to perform, but the fact of its being so is no doubt the reason why, comparatively speaking, so few serious accidents happen in it. It is not so much that the best, most skilled workmen are chosen to perform pillar drawing, as that the men, being alive to the dangers, are more on the alert and careful to

protect themselves.

Sometimes, if not very often, in chamber or room-and-pillar working it is the custom to work out the rooms or chambers and leave pillars all the way from the shaft to the boundary line over large areas; in other words, the portion of the roof left standing on pillars is very extensive. Mines so worked have sometimes been spoken of as mines on stills. To this mode of proceeding there are several serious objections. By leaving the pillars until the boundary has been reached, a large number of airways and roadways have to be kept open and in repair, and this number is constantly increasing until the limits of the workings have been reached. This circumstance renders the ventilation more difficult, and thereby increases risks of accident. Moreover, the length of time during which the old rooms and pillars are left open and standing increases the danger of squeeze and creep



Fig. 5. F1G. 6.

setting in, by which a large area may in a short time be overrun. this method, the pillars first formed are last removed, and hence it happens

this method, the philars hist former are last removed, and hence it happens that a large number of them crack and give way under the combined action of atmospheric agencies and great pressure. Even if they resist these actions well, the quality of the coal greatly deteriorates by the long exposure.

For the above reasons, it is the best practice to carry on the two workings (working the rooms and drawing the ribs and pillars) simultaneously. By so doing, the length, mean duration of the roadways, etc. are reduced, and the pillar coal obtained in much better condition; and, in order to concentrate the workings as much as possible, the two operations should go on as closely together as practicable. With fairly thick and very soft coals, the rapid working up of the rooms and equally quick drawing of the ribs, as soon as the rooms are driven their full distance, is essential to economical working; for delay in extracting ribs and pillars in such circumstances results in their getting crushed and the coal lost or largely ground to slack, waste of props and material, disordered ventilation, and shortened life of the mine

Methods of drawing pillars vary according to the inclinations of the seams, the nature of the roof and floor, and the character of the coal. Figs. 5 and 6 show the common methods. In Fig. 5, A, B, and C, the drawing begins by cross-cutting the fast ends of the pillars to obtain a retreating face. A shows a method for soft coal and narrowing pillars, B for wide

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AND OF COMMENCE DIRECTION OF DAMES OF INCIDENCES.	Domonles	ACTIBIL ES.	Checker coal from Exeter. Checker coal M. W. coal pile. Checker coal bottom of Clear Spring colliery. Clear Spring Pittston vein glassy coal. Clear Spring Marcey checker coal. Clear Spring Marcey checker coal. Clear Spring Marcey checker coal. Clear Spring Marcey. Very good test. Checker coal. Clear Spring Marcey. Very good test. Clear Spring Marcey. Knot in block. Not fair test. Clear Spring reddish glassy coal. Clear Spring reddish. Not fair average test.	
TEN .	Crushing Weight, Tons. Deduced.	Per Cu. In.	2.87 4.12 4.20 8.00 5.16 5.17 5.17 5.17 (?)	4.67
OF DA	Crus Weight Dedu	Per Sq. In.	2.418 2.08 1.65 0.80 1.34 1.72 1.41 3.45 1.12 (?)	
T DATE OF	Breaking Weight. Tons. Deduced.	Per Cu. In.	3.02 3.23 3.02 3.02 3.02 3.02	2.70
70 71 10		Per Per Per Sq. In. Cu. In.	©©©©© 989 1.158 1.158 1.10 1.10	ge
	Weight Sustained.	Crush- ing. Tons.	328878878888	Average
		Break- ing. Tons.	EEEE 81888888888	
	f Test	Height.		
	Dimensions of Test Piece.	Cength. Width. Height	00 to 44 to 12 44 44 44 12 10 나무 에 14 14 14 14 14 14 14 14 14 14 14 14 14	
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l	nber est.	nuN F 10	110087765743121	

the end pillars. taken in two lifts, C is for harder co shows it taken in lifts. D and E sho pillars cut into sto be drawn by side o lifts, according t character of the co inclination of the thickness of the and the strength or ness of the roof and Fig. 6 shows some methods used in ro the pillars in steep ing, thick beds of a cite. To get the co of A, a skip is tak the side, as shown. cessive skips are taken off until the is removed, the keeping the man open to the heading low as a means of re The pillar betwee and B is very sim .worked. To remov between B and C, row chute or head driven up the m and cross-cuts put right and left a few from the upper Shots are placed i four blocks of coal formed, as shown, they are fired simul ously by battery. operation is repeat each descending po unless the pillar b to run. A pillar which the coa started to run is si to the right of C.

To secure the hi percentage of pillar a method shoul adopted that will vent squeezing or coing, if possible. Al pillars in a panel m taken out at the time by end lifts in a way as to keep the of all the lifts in lin perpendicular t sides of the pillar the pillars are drav lifts of three or pillars each, the ce of the face of the lying in a straight that makes an ang

about 40° with the

(See also "Flushing of Culm," which is described fully on of the pillars. page 314.)

Gob fires are due to the spontaneous ignition of coal, and are most likely to occur in pack walls and gobs where there is an insufficiency of air. Ample

ventilation is the best preventive.

Spontaneous Combustion.-According to Prof. Able, Dr. Percy, and Prof. Lewes, the causes of the spontaneous ignition of coal are: First, and chiefly, the condensation and absorption of oxygen from the air by the coal, which of itself causes heating, and this promotes the chemical combination of the volatile hydrocarbons in the coal and some of the carbon itself with the condensed oxygen. This process may be described as self-stimulating, so that, with conditions favorable, sufficient heat may be generated to cause the ignition of portions of the coal. The favorable conditions are: A moderately high external temperature; a broken condition of the coal, affording the fresh surfaces for absorbing oxygen; a supply of air sufficient for the purpose, but not in the nature of a strong current adequate to remove the heat; a considerable percentage of volatile-combustible matter or an extremely divided condition. Second, moisture acting on sulphur in the form of iron pyrites. The heating effect of this second cause is very small, and it acts rather by breaking the coal and presenting fresh surfaces for the

absorption of oxygen.

Coal Storage.—Prof. Lewes gives the following recommendations for the storage of coal: "The coal store should be well roofed in, and have an iron floor bedded in cement; all supports passing through and in contact with the coal should be of iron or brick; if hollow iron supports are used, they should be cast solid with cement. The coal must never be loaded or stored during wet weather, and the depth of coal in the store should not exceed 8 ft., and should only be 6 ft. where possible. Under no condition must a steam or exhaust pipe or flue be allowed in or near any wall of the store, nor must the store be within 20 ft. of any boiler, furnace, or bench of retorts. No coal should be stored or shipped to distant ports until at least a month has elapsed since it was brought to the surface. Every care should be taken during loading or storing to prevent breaking or crushing of the coal, and on no account must a large accumulation of small coal be allowed. These precautions, if properly carried out, would amply suffice to entirely do

away with spontaneous ignition in stored coal on land."
When the coal pile has ignited, the best way to extinguish the fire is to remove the coal, spread it out, and then use water on the burned part. The incandescent portion is invariably in the interior and when the fire has gained any headway usually forms a crust that effectually prevents the water from acting efficiently.

MODIFICATIONS OF ROOM-AND-PILLAR METHODS.

Some modifications of the room-and-pillar plan shown in Fig. 1 can usually be applied to seams whose dip does not exceed 3°. When the pitch is greater, rooms are often turned off toward the rise only, and the cross-entries driven correspondingly closer together. When the pitch is from 5° to 10°, the cars may still be taken to the face if the rooms are driven across the pitch, thus making an oblique angle with an entry or gangway, the rooms being known as room breasts.

Buggy Breasts.—For inclinations between 10° and 18°, that is, after mule haulage becomes impossible and until the coal will slide in chutes, buggies are often used. Fig. 8 shows a buggy breast in plan and section. Coal is loaded into a small car or buggy c, which runs to the lower end of the breast and there delivers the coal upon a platform l, from which it is loaded into the mine car. The refuse from the seam is used in building up the track,

Another form of buggy breast is shown in Fig. 7. Here the coal is dumped directly into the mine car from the buggy. If the breast pitches dumped directly into the mine car from the buggy. If the breast pitches less than 6°, the buggy can be pushed to the face by hand, but in rooms of a greater pitch, a windlass is permanently fastened to timbers at the bottom of the breast, while the pulleys at the face are temporarily attached to the props by chains, so that they can be advanced as the face advances. The rope used is from \(\frac{1}{2}\) in. in \(\frac{1}{2}\) in. in diameter, and any form of ordinary horizontal windlass can be used. With the windlass properly geared, one man can easily haul a buggy to the face of a breast in a few minutes time. The buggy runs upon 20-lb. T rails spiked with $21'' \times 1''$ spikes upon $2'' \times 4''$

hemlock studding sawed into lengths of 14 ft. This system has thoroughly tested by the Delaware & Hudson Canal Co., Scranton, This system has

and has proved a very successful and economical one.

Chute Breasts.—Seams pitching more than 15° are usually worked chutes, or self-acting inclines. When the pitch is between 15° and 30°, serion is laid to furnish a good sliding surface for the coal. On inclinate of less than 18° to 20°, it is usually necessary to push the coal down chute. Sheet iron is not required on pitches above 30°. It must be remembered, whethere is the second of the secon bered that these pitches are only fair averages, as much depends on character of the coal. Anthracite slides more easily than bituminous. secure the best returns from a coal seam, the slope or shaft should be dr to the basin, and the lowest gangways or levels first driven to the prop limits, and the coal then worked retreating toward the slope or sl Practice is, however, usually contrary to this, and the upper levels or gways are turned off first, and working places opened out as rapidly as gangway is driven. Fig. 9 shows a method of grouping rooms that ma

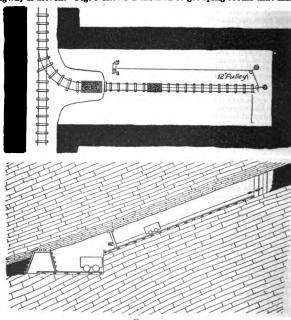


FIG. 7.

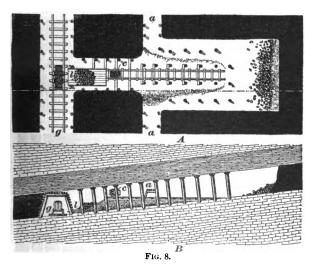
used where the pitch is from 8° to 20°, the straight heading being driver the strike and the other headings at such angles as will give a good gr

for haulage purposes.

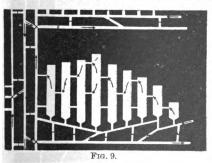
The pillar-and-stall system is a modification of the room-and-pillar The pillur-and-stall system is a modification of the room-and-pillur which it is similar in all respects excepting in the relative size of the pill and breasts. The stalls are usually opened narrow and widened ins according to conditions of roof, floor, coal, depth, etc., being from 4 to 6 in the single-stall method, with the pillars about the same width. Fig A and B, shows single and double stalls. This system is adapted to weak and floor, or strong roof and soft bottom, to a fragile coal, or when ample support is required, and is particularly useful in deep seams we great roof pressure. Double stalls are often driven from 12 to 15 vd. wide. with an intervening pillar of sometimes 30 yd.

The following are a few of the applications of the pillar-and-stall method of working as they are carried out in some of the leading coal fields of

Connellsville Region (H. L. Auchmuty).—Fig. 11 shows the common method used in the Connellsville, Pa., region. The average dip is about 5%. The face and butt headings are driven, respectively, at right angles to each other on the face and the butt of the coal. The face headings leave

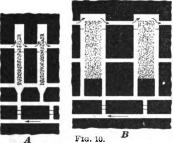


the main butts about 1,000 ft. apart, while from these face headings, and 400 ft. apart, secondary butts are driven, and again from these butts on



the face of the coal the rooms or wide workings are excavated to a length of 300 ft., this having proved the most convenient length for economical working. Room pillars have a thickness of 30 to 40 ft., while the rooms are 12 ft. in width and are spaced 42 to 52 ft. between centers, pending on depth of strata over the coal. The headings are 8 ft. wide, and in all main butts and faces the distance between centers of parallel headings is 60 ft., leaving a solid

rib of 52 ft. A solid rib of 60 ft. is also left on the side of each main heading. The average thickness of cover at the Leith mine, which is here described and which may be considered as a type of the reg is 250 ft., the overlying measures being alternated layers of soft si and coal for 4 ft. The bottom an 18" layer of hard fired



and coal for 4 ft. The botton an 18" layer of hard firet and slate. These floor and materials are soft, and are ead disintegrated by air and wa At some mines, cover will re as much as 700 ft., and the di 5% (as at Leith) is much hear at some points on eastern crop, and will run as high as flattening off as the synclinal of the basin is reached, until almost level. In some localit the material below coal is h limestone, requiring blasting remove it, and at other platter of slates are much molid than at Leith, and not refull this state and the contract of the state and the contract of the same much molid than at Leith, and not refull this teach.

of drawing ribs is one of the beauties of the system, since it is harder to successfully in a soft coal like the Connellsville coal than in hard coal.

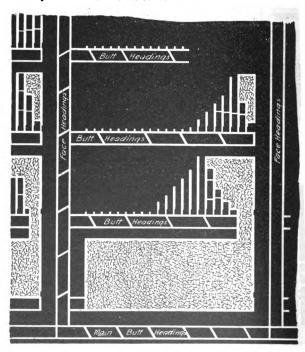


Fig. 11.

coal itself is firm. When necessary to protect the top or bottom, 4 to 6 in. of

coal are left covering the soft material.

The method as given above is often applied to a whole series of butts (4 or 5) at once instead of to butt by butt, as shown in Fig. 11. In this case, work is started at the upper end of the uppermost butt and progresses, as shown in Fig. 11; but, after cutting across the butt heading from which the rooms were driven, the butt heading itself and the upper rooms from the second butt, or that just before, are likewise drawn back by continuous slices being removed from the rooms of the upper butt, and on across the enext lower butt, etc., all on an angle to the butts, and so continued as the operations progress, until another butt is reached, etc., thus gradually making a longer and longer line of fracture, which is only limited by the number of butts it is desired to include at one time in the section thus mined. This works very nicely and makes long even lines of fracture, the steps of the face of the workings (in the rib drawing) being about 30 ft. ahead of one another.

Pittsburg Region (H. L. Auchmuty).—The coal is worked in much the same way as in the Connellsville region, except that a different system of drawing ribs is used. The coal is worked on the room-and-pillar system, with double entries, with cut-throughs between for air, and on face and butt, entries are about 9 ft. wide, and the rooms 21 ft. wide and about 250 ft. long; narrow (or neck) part of room, 21 ft. long by 9 ft. wide; room pillars, 15 to 20 ft. wide, depending on depth of strata over the coal, which is from a few feet to several hundred feet. The mining is done largely by machines of various types. Coal is hard, of course, and, in many places, the roof immediately over the coal is also quite hard. There are about 4 ft. of alternate layers of hard slate and coal above the coal seam. Rooms are mined from lower end of butt as fast as butt is driven, the ribs being drawn as mining progresses. As the coal is harder than in the Connellsville region, thickness of coal pillar between parallel entries is somewhat less.

Clearfield Region (G. F. Duck).—The butt and face are not strongly marked in the B or Miller seam, the one chiefly worked in this region. Where possible, these cleavages are followed in laying out the workings, but the rule is to drive to the greatest rise or dip and run headings at right angles to the right and left, regardless of anything else. The main dip or rise heading is usually driven straight, and is raised out of swamps or cut down through rolls—very common here—unless they are too pronounced, when the heading is curved around them. The same is true of room headings, except that they are more usually crooked, not being graded except over very minor

disturbances.

As the B seam rarely runs over 4 ft. in thickness, and is worked as low as 2 ft. 8 in. in the haulage headings, the roof is taken down to give 5 ft. to 5 ft. 2 in. above the rail, or 5 ft. 8 in. to 5 ft. 10 in. in the clear. Where the resulting rock is taken outside, the headings are driven 10 ft. wide with 4ft. of pillar, roof taken down in haulage heading but not in air-course. Where the rock is gobbed underground, the haulage heading is 18 to 2 ft. wide, air-course 10 ft., pillar 24 ft., and roof taken down in haulage heading only. The thinner the coal, the wider the heading. It is more economical to haul the rock to daylight. The bottom generally consists of 3 ft. to 5 ft. of hard fireclay, frequently carrying sulphur balls.

In numerous places, the sand rock is immediately over the coal, but in most cases there is from 3 to 5 ft. of slate before the sand rock is reached.

In numerous places, the sand rock is immediately over the coal, but imost cases there is from 3 to 5 ft. of slate before the sand rock is reached. Room headings are driven 280 ft. apart, haul rock to daylight, heading 10 ft. wide with 24 ft. pillar to 10 ft. air-course, in which roof is left up. A 15 ft. to 25 ft. chain pillar is left between air-course and faces of rooms from the lower heading, every fourth to eighth of which is driven through to the air-course to shorten the travel of the air. The rooms are therefore 180 to 200 ft. long, and the men push the cars to the face, an important economical item

in this thin coal.

Rooms are 21 ft. wide with a 15 ft. pillar, and a 15 ft. chain pillar is left between the first room on any room heading and the main heading, are food in not taken down in rooms. Main-heading track is usually 30-lb, iron, room heading, 12 lb., and $2'' \times 4''$ strap iron set on edge is used in the rooms in low coal. Mine cars hold from 600 to 800 lb. in low seams, and 1,500 to 2,000 lb. in the so-called thick seams, i. e., 3 ft. 8 in. to 4 ft. thick.

Reynoldsville Region.—The measures are very regular, and the method employed the typical one shown in Fig. 1. The average thickness of the principal seam is 64 ft. and the pitch is 3° to 4°. The coal is hard and firm

and contains no gas; the cover is light, and on top of the coal there 3 or 4 ft. of bony coal; the bottom is fireclay. Drift openings and the dou entry system are used. Both main and cross-entries are 10 ft. wide, wit 24-ft. pillar between. The cross-entries are 600 ft. apart, and a 24 ft. ch pillar is left along the main headings. The rooms are about 24 ft. w and open inbye, the necks being 9 ft. wide and 18 ft. long. The pillars from 18 to 30 ft. thick.

West Virginia (James W. Paul).—The general plan of working the Pi burg coal in the northern part of West Virginia is as follows. The comeasures vary from 7 to 8 ft. in thickness, and have a covering vary from 50 to 500 ft. The coal does not dip at any place over 5%. In most places coal is practically level, or has just sufficient dip to afford drainage. The us method of exploitation is to advance two parallel headings, 30 ft. apart, on face of the coal. At intervals of 500 to 600 ft., cross-headings are turned to 7 and left, and from these headings rooms are turned off. These cross-headi are driven in pairs about 20 or 30 ft. apart. Between the main headings s

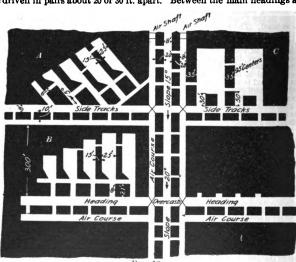


FIG. 12.

the first room is left a block of coal about 100 ft., and on the cross-headir there is often left a barrier pillar of 100 ft. after every tenth room.

The headings are driven from 8 to 12 ft. wide, and the rooms are ms 24 ft. wide and 250 to 300 ft. long. A pillar is left between the roo about 15 to 20 ft. wide. These pillars are withdrawn as soon as the par of rooms has been finished. The rooms are driven in from the entry about 0 ft. wide for a distance of 20 ft., and then the room is increased in width one side. The track usually follows near the rib of the room. Cross-con the main and cross-headings are made every 75 to 100 ft., and in roo about every 100 ft., for ventilation.

about every 100 ft. for ventuation.

The double-heading system of mining and ventilation is in vogue. Over casts are largely used, but a great many doors are used in some of mines. Rooms are worked in both directions. This is the gene practice when the grades are slight. When the coal dips over 15, frooms are driven in one direction only. In this case, the rooms made longer, as much as 350 ft. It is the custom then to break abovery third room into the cross-heading above (a practice ill advise The floor of this bed of coal, being composed of shale and fireclay, of

heaves, especially when it is made wet. Some trouble is at times experienced by having the floor heave by reason of the pillars being too small for

the weight they support.

The dimensions of rooms and pillars given are for a mine (with covering 300 to 500 ft. thick) having a fairly good and strong roof. Where roof, bottom, and thickness of cover change, these dimensions are altered to suit the requirements. The main-heading pillars may be reduced to 30 or 40 ft.; the rooms may be made 15 ft. wide with 12 ft. pillars, and no barrier pillars may be left on the cross-headings.

The foregoing plan is very much followed in other parts of the State; at least an attempt is made to do so, but local disturbances often require changes in the plan. This plan is followed on some parts of New River, and also in the Flat Top field.

Alsbama Methods (J. E. Strong).—Fig. 12 shows the common methods used in working the Alabama coals. The seams now working vary from 2 to 6 ft. thick, and they pitch from 2° to 40°. Where the seams are thin, the coal is hard, and pillars of about 20 to 30 ft. are used to support the roof.

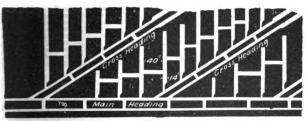
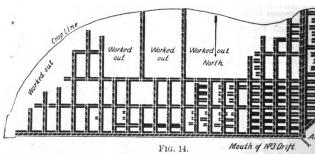


Fig. 13.

The thick seams are soft and easily broken, and much larger pillars are left. The character of bottom and top varies; fireclay bottom and slate roof are usually found with the thick seams, and hard bottom and sandstone roof with the thin seams. The general plan of laying out the mine is to drive the slope straight with the pitch of the seam; this is usually on the butts of the slope straight with the pitch of the seam; this is usually on the butts of the coal. A single-track slope is 8 ft. wide, and a double-track slope is 8 ft. cross-headings are driven or turned from the slope water level every 300 ft.; air-courses are driven parallel on either side of the slope. Where an 8 ft. slope is driven, 30 ft. of pillar are left between the slope and airway and for a 16 ft. slope, 30 ft. of pillar. The size of pillar, however, depends largely on the character of the roof and thickness and strength of coal. On the lower side of the headings, pillars from 20 to 60 ft. are left on the entry before turning the first room. The rooms are worked across the pitch on an angle of about 5° on the rail, Fig. 12, A, when the coal does not pitch greater than 20°; where the pitch is greater, chutes are worked and the rooms are driven straight up the pitch (Fig. 12, B). In a few cases, where the pitch is not greater than 15°, double rooms are worked with two roadways in each room (Fig. 12, C). A rope with two pulleys is used, and each track keeps the rib side of the room, the loaded car pulling up the empty on the opposite side of the room; distance between room centers, about 42 ft. Where single rooms are worked, the room is driven narrow Where single rooms are worked, the room is driven narrow about 42 ft. (8 ft. wide) for 21 ft., when connections are made with the room outside of it; the room is then widened out to about 25 ft., sloping gradually until this width is at tained; pillars of from 10 to 20 ft. thick are left between the rooms, and cross-cuts for ventilation are made about every 50 ft.; every third or fourth room is driven through to the entry above; pillars are then drawn back to the entry stumps or pillars. The average cover over the coal now working is from 100 to 600 ft. Air-courses usually have an area of 30 ft., and sufficient coal is taken out to give this area, the roof and bottom being left.

George's Creek District, Md.—Fig. 13 shows the method used in the George's Creek field, Maryland. The coal shows no indication of cleats, and the butts and headings can be driven in any direction. The main heading is driven to secure a light grade for hauling toward the mouth. Crossheadings making an angle of 35° to 40° are usually driven directly to the

Pillars are drawn as soon as the rise, and of the dimensions shown. are completed, being attacked on the ends and from the rooms on side, the coal being shoveled to the mine car on a track in the room. wide pillars are split. No effort is made to hold up the overlying strate the entire bed is removed as rapidly as possible. An extraction of 85% bed is considered good work. A section of the seam is as follows: coal, 10 in.; coal, 7 ft.; slate, \(\frac{1}{2} \) in.; coal, 10 in.; slate, \(\frac{1}{2} \) in.; coal, 10 in.; slate, \(\frac{1}{2} \) in.; coal, 10 in.; firstate. The top bench is bony and frequently left in place to pr



disintegration of the roof by the air. Above this coal is from 8 to 10 "rashings," consisting of alternating thin beds of coal and shale, that is brittle, and requires considerable timber to keep it in place.—("Mine Minerals," Vol. 19, page 422.)

Blossburg Coal Region, Pa.—Coal is generally mined from drifts, but few cases by slopes. Fig. 14 shows the general method adopted; the beare run at right angles to the slips; the breast pillars are split by a cheading and taken out as soon as the breasts are finished. The gan pillars are taken out retreating from the crop or boundaries of the prop

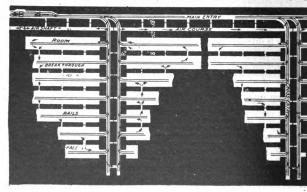


FIG. 15.

The general average of the coal seams is not over 31 ft., accompanie fireclay and some iron ore. The dip of the veins is about 34.—("Mineral of the veins is about 34.—("Miner

Minerals," Vol. 19, page 126.)
Indiana Coal Mining.—Fig. 15 shows the double-entry room-and-method as used in Indiana. The entries are generally 6 ft. high, 8 ft. b

the minimum height required by law being 4 ft. 6 in. The rooms are from 21 to 40 ft. in width. The mines are generally shallow. The rooms in Fig. 15 are shown as widened on both ribs, but a more usual method in this locality is to widen the room on the inbyerib, leaving one straight rib for the protec-tion of the road in the room.—("Mines and Minerals," Vol. 20, page 202.) lows Cosl Mining.—The coal lies at a depth of 200 ft. below the surface, and

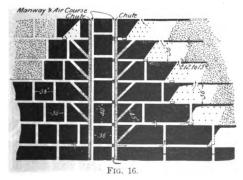
is geologically similar to that of the Missouri and Illinois fields. It lies in lenticular basins extending northwest and southeast and outcropping in the larger river beds. The seams are practically level, non-gaseous, and genstones, and limestones, which are generally of a yielding nature, giving a strong, good roof for mining. There are three distinct seams, the lower one, which varies from 4 to 7 ft. in thickness, being the only one worked. The coal is a hard, brittle, bituminous coal that shoots with difficulty, but is

excellent for steam and domestic uses. About Centerville, the coal has a distinct cleat, but elsewhere in the State this is lacking.

The entry pillars along the main roads are 6 to 8 yd. thick, for the cross-entries 5 to 6 yd., and for the rooms 3 to 5 yd. Room pillars are drawn in when approaching a cross-cut. Both room-and-pillar and longwall methods are in use, with modifications of each. In the room-and-pillar system, the double-entry system is almost invariably used in the larger mines. Rooms are driven off each entry of each pair of cross-parties of system, the double-entry system is almost invariably used in the larger mines. Rooms are driven off each entry of each pair of cross-entries at distances of 30 to 40 ft., center to center; the rooms are 8 to 10 yd. in width, and pillars 3 to 4 yd. The rooms are narrow for a distance of 3 yd., and then widened inbye at an angle of 45° to their full width. They vary from 50 to 100 yd. in length, and the road is carried along the straight rib.

When double rooms are driven, the mouths of the rooms are 40 to 50 ft.

apart, and they are driven narrow from the entry a distance of 4 or 5 yd.



A cross-cut is then made connecting them, and a breast 16 yd. wide is driven

up 50 to 60 yd. The pillar between each pair of rooms is 12 to 15 yd.

In pillar and stall work, the stalls are usually turned off narrow and widened inside, the pillar varying from 5 to 8 yd. The stalls are 30 to 40 yd. in length, and the pillars are drawn back. When the stalls are driven in

pairs, the pillar 8 to 10 yd. in width is carried between them.

Longwall.—The main haulage road runs in each direction from the foot of the shaft, and on both sides of this diagonal roads are turned at an angle of 45°, or parallel to the main haulageway. These are spaced 10 yd. apart and driven 50 to 60 yd., when they are cut off by another diagonal road. Panel breasts are used where the conditions are such as to induce a squeeze. Rooms are turned narrow off entries and are arranged in sets of 6 to 12 rooms, with a pillar 10 to 20 yd. wide between the sets of rooms. When the rooms have progressed a short distance from the entry, they are connected by cross-cuts, and the longwall face is carried forward from this point. Packs are built and the roof allowed to settle, as in longwall. The wide pillars are taken out after the roof has settled.

Ventilation.—The system of ventilating the workings usually employed is that of conducting the air to the inside workings by means of an air-course forming the back entry of each haulage road. From this point it is carried along the face of the rooms, through the breakthroughs or cross-cuts in the room pillars, returning thence to the haulage road, which is usually made the return airway. When, however, the mine is ventilated by means of a furnace or an exhaust fan, the intake airway is usually made the haulage road, in order to avoid doors at the shaft bottom.

The Fosis, California, method is shown in Fig. 16. The coal seam averages 7 ft. of clear coal, and pitches 60°. This system was adopted in a portion of the mine to get coal rapidly; for, at this point, a short-grained, slate cap rock came in over the coal, making it difficult to keep props in place. The floor is a close blue slate and has a decided heaving tendency. The roof is an excellent sandstone. There is a small but troublesome amount of gas. Two double chutes are driven up the pitch at a distance of 36 ft. apart, connected every 40 ft. by cross-cuts. One side of each chute is used for a coal chute and the other for a manway and air-course. At a distance of 12 yd. apart small gangways are driven parallel with the main mine gangways. These are continued from each chute a distance of 300 ft., if the conditions warrant it. The top line is then attacked from the back end and the coal is worked on the cleavage planes; the breast, or room, therefore consists of a 12-yd. face, including the drift or gangway through which the coal is carried to the chutes: a rib of coal (2 or 3 ft.) is left between the breast to keep the rock from falling on the breast below. Thus in each breast the

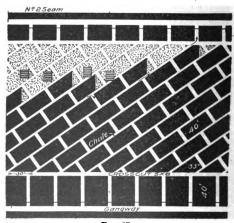


FIG. 17.

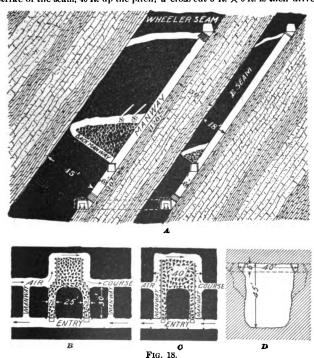
miners have a working face of about 15 or 16 yd., and as the coal is directed to the car by a light chute, moved along as the face advances, the coal is delivered into the cars at small cost, and but little loss results from the falling coal, as a minimum of handling is thus obtained. Immediately above each gangway, and starting from these main chutes, an angle chute is driven at about 45°, connecting with the breast gangway above it, and into these chutes the coal from that breast is delivered, runs into the main chute, and from it is loaded into the mine cars in the main gangway. These angle chutes serve as a means of keeping the main chute full, and at the same time giving each breast an opportunity to send out coal continuously. They also serve the purposes primarily intended, of saving the coal from breakage, by giving it a more gradual descent into the full chute. The breast gangways are driven 5 ft. wide. No timbers are needed in these gangways, as they are driven in the coal, except on the foot-wall or floor

side, which, as before stated, is a firm sandstone. It is found safest to leave a rib of coal on the top of the breast 2 or 3 ft. thick, until the working face has passed on 12 or 15 ft., when this rib is cut out and thus all the coal extracted, the roof caving behind and filling in the opening. As cross-cuts are driven every 36 ft., ventilation is kept along the working faces, and a safe and effectual means of securing all the coal in the seam is thus attained.

Fig. 17 shows another system used in No. 7 vein at the same place. The seam averages 7 ft. of coal. The roof is shelly and breaks quickly, hence

the coal must be mined rapidly.

In this system the gangway chutes are driven at right angles with the strike of the seam, 40 ft. up the pitch; a cross-cut 5 ft. \times 6 ft. is then driven



parallel with the gangway. From this cross-cut, chutes are driven at same distance apart as the gangway chutes (30 ft.), at an angle of 35°, and cross-cuts are driven every 40 ft. between chutes, for ventilation. After a panel of five or more chutes is driven up the required distance, work is commenced on the upper outside pillar and the pillars on that line are drawn and the next line is attacked, and this is continued until the panel or block is worked down to the cross-cut over the gangway. About every 80 ft. in this level it is found advantageous to build a row of cogs parallel with the strike of the seam as the pillars are drawn. This serves to save the crushing of the pillars, and prevents any accidents from falls of rock. But few timbers are required by this system.—("Mines and Minerals," Vol. 19, page 145.)

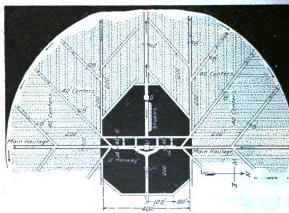


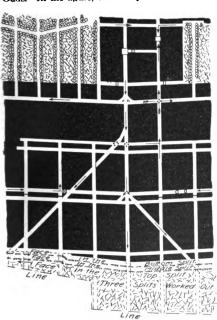
Fig. 19.

the air-course until the hanging wall is reached, manways, called back ways, being maintained as before. A triangular section of coal is mined as shown in A, Fig. 18, and the room filled with loose coal. The full these of the seam is now taken off, shots being first placed at S, coal be drawn out at the bottom as required. Section D, Fig. 18, shows a methodoling a pillar. In doing this, the manways are moved back into pillar each side 10 ft. or so, by mining on the lower bench as before, holes are drilled into the roof with long drills, which bring down as muthe overhanging part as can be reached.—("Mines and Minerals," Vopage 37.)

MODIFICATIONS OF LONGWALL METHOD.

Fig. 19 shows a good arrangement of the main and temporary hau ways in a flat seam. The chief object in any plan of longwall workings have the permanent roadways the arteries of the system, providing the direct route from all sections of the mine to the shaft. The temporary is the system of the system of the system of the sections of the mine to the shaft.

roads or working places are only maintained for a distance of 60 to 100 yd., until cut off by subroads branching at regular intervals from the main roads. In the figure, full heavy lines indicate the permanent haulageways,



except only the main intake airway (12 ft. wide), running west from the downcast shaft D, and the main return air-course (12 ft. wide) leading from the face on the east side to the manway around the upcast U. which is the hoisting The full light shaft. lines indicate the diagonal subroads, driven to cut off the working places, shown by the dotted lines. The stables are located as shown in the shaft pillar, between the two shafts, where they will not contaminate the air going into the mine, but will receive air fresh from the downcast and discharge it at once into the upcast cur-This position also rent. affords ready access from either shaft in case of accident, and for the handling of feed and refuse. The pumps may be located in any convenient position at the foot of the upcast. The shaft bottoms are driven 14 ft. wide nearly through the shaft pillar, and are

Fig. 20. Fig. 21. is to provide for the future need, when the size of the workings will demand that the

continued 10 ft. wide north and south through the gob. The width of all other roads and subroads is made 8 ft. The extra width of the straight road through the hoisting shaft

mine be ventilated in four sections or splits; and these two roads will then each form the return of two sections. This will be accomplished by overcasting the main road forming the shaft bottom, and carrying half the current by this means to the east face, where it is again divided. The same thing is done on the west side. The divided currents, after traversing the

faces of their own respective sections, unite and return to the hoisting shaft by the main haulage road. When the roof is very solid, the gob roads turn off the entries at 45°, and

may be a considerable distance apart, so that the tracks can be turne along the working face and the mine cars loaded at the face. When roof is tender, making it impossible to maintain sufficient room for the rears to pass along the face, gob roads are turned off near together, and mine cars run to the road heads, to which points the coal is shovele hauled in buckets. When the working face has reached such a dist from the bottom of the shaft that it becomes impossible to work rapenough to avoid the destructive weighting action of the roof, the minust be divided into panels or sections, the working face of each of wean be advanced at the proper rate.

can be advanced at the proper rate.

Figs. 20 and 21 show a plan and section, respectively, of two met largely used in Europe for working thick pitching, contiguous seam hard, long-grained coal. From the foot of the shafts, levels are drive the strike, and jig roads turned off these in the top seam at right at up the pitch. The working faces are advanced in the same horize plane, the lower one being always ahead. The coal from the two learns is run through horizontal passages to the upper seam, where lowered to the levels below by means of jigs or gravity planes. The setween the seams and the refuse obtained in mining are used to fill the faces advance. This gobbing must be done quite thoroughly, in ord prevent excessive settling of the roof and consequent crushing of the coal faces. Where spontaneous combustion is liable to occur, it is advisable to use this method, but rather that shown in the lower portic the figures. Slopes, or inclined planes, are driven down the pitch from levels to the basin, or, if possible, to the boundary line, where the wor faces are formed by driving levels to the right and left of the ends o slopes. The working faces are here also kept in a horizontal plane the lower one farthest up the pitch. The coal from the two upper seat taken through tunnels or flats to the slopes in the lower seam, and hoist the shaft bottom. Here all the inclined planes or other passages are is an of coal is left in the mine when worked from the basin upwards, and effects of squeezes are not felt to any great extent, as the weight of the is thrown on the gob. Where there is not sufficient refuse material to five with, it is taken into the mine from the surface, or from another adja mine having an extra amount, of stowing material.

It is not necessary that the slopes be sunk to the boundary line, in whease the main-slope pillars should be large and left in so that the workings, as they are called, can be continued downwards when desi In this way, the first cost of opening up is greatly reduced. The vention of these workings is quite simple, the intake being split at the ends of main entries, or slopes, and the air forced along the different working fit to the right and left, and thence to the upcast by way of the main-real airways. If at all possible, it is advisable to provide an outlet near faces of the rise workings that are advancing upwards, because the liging sees cannot be forced down-hill with satisfaction unless an excess velocity of the air-current be maintained. These systems are well aday to deep or shallow mines, and to give maximum outputs for minim development, provided the work is carried on quickly and steadily.

to deep or shallow mines, and to give maximum outputs for minin development, provided the work is carried on quickly and steadily.

Overhand-Stoping Method.—Where several thick and heavily pitch seams, in which considerable firedamp is given off and the roof of freely, are to be worked, a shaft is sometimes sunk in the adjacent strand at certain distances horizontal tunnels are driven to the coal see From these tunnels, levels or haulage roads are driven in each sean the right and left, provided the seams are not so close together as to mit more profitable to use rock chutes or tunnels, through which the class run from one seam into the other. At certain intervals, depending on length of the lifts horizontally, pairs of headings, usually called dips, driven up the pitch until they intersect the levels and tunnels ab Headings are turned off these dips to the right and left, parallel to the milevels or haulage roads, and when they meet or have reached their liborizontally they are holed, or cut through, by cross-cuts driven on pitch. The working faces thus formed are then carried back, as shown Fig. 22. Skips are taken off the face and the roof allowed to cave in a each operation and fill up the gob behind. The order of working is sthat the top faces are worked in advance of the lower ones. The owhich are taken to the working faces, are handled in the dips by bala carriages, or back balances, as they are termed in some localities.

barney, or balance, runs on a narrow track in the middle of the track for the carriage on which the car is placed. The barney will raise the carriage with the empty car on it, and the carriage and loaded car will hoist the barney. These gravity planes are only made one-half the length of the dips, or about 150 ft., in order that greater safety may be secured and shorter ropes used. One is placed in the lower half of one of the pairs of dip headings, and another in the upper half of the other, thus necessitating that the cars be changed from one gravity plane to the other midway along the dips. This is done by taking the car off one carriage and pushing it through a breakthrough or cross-cut to the other. Fig. 22 shows the method of working these lifts in some parts of England and Belgium where the seams are gaseous, and some of them quite thick. The face is stepped more or less deeply, depending on the pitch, in order to protect each miner from the falling coal of his neighbor. The men reach the higher portion of the working face through timbered manways. The coal is generally run down chutes to the cars below, but in some places it is run to the end of the gangway below by means of inclined chutes, or spouts, laid on the gob. The essential feature for the successful operation of this system is the close and careful stowing of the gob between walls. In Belgium, cord wood and brush wood are very largely used for gobbing material or stowing between the regular timbers. All the coal, except very thin vertical pillars, is taken out. Where there is

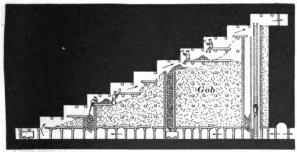


FIG. 22.

much firedamp, the miners simply nick the coal and leave it stand over night, during which time the gas either forces it off the solid or so loosens it that the miner can easily take it off with a pick. (See also Highly Inclined Mineral Deposits.)

METHODS OF MINING ANTHRACITE.

A perfectly flat seam of anthracite is seldom found in America, and even where a portion of the seam may be found lying comparatively flat, such sudden changes in dip must be expected that a system adapted to working on a pitch is almost universally used. A breast may start on a low pitch and the pitch may increase gradually until it becomes vertical, or the reverse may be the case. The cleat is usually lacking in anthracite, and the direction of driving the breasts is determined largely by the pitch and by haulage considerations.

For pitches up to 30°, the methods shown in Figs. 1.7, 8, 9, 10, 12, and 13 are, in general, applicable, with certain changes due to local considerations. There is considerable difference in the methods of opening rooms in anthracite and bituminous mines, owing to variations in the characteristics of the coals and to the fact that anthracite will slide on chutes of less inclination than bituminous coal. Where the pitch does not exceed 4°, the rooms are turned off at right angles to the gangway. In moderately thick coal seams pitching between 4° and 18°, the rooms are generally driven across the pitch, forming room breasts, thus securing a grade that permits the haulage of the cars to the face.

There are two methods of mining thick coal in breasts when near (1) The breasts are opened out and driven to the limit in the lower be coal, and the top benches are blown down afterwards, beginning at the and working back. (2) When the roof is good and there is no dange falling and closing up the workings, the upper benches may be wor the opposite direction, beginning at the gangway and driving towar limit of the lift, or the working of the upper bench may follow up that lower bench. When the seam is less than 12 ft., the top is suppor props; in thicker seams, the expense is so great for propping that but attempt is made to support the roof. In the thicker anthractic (notably the Mammoth), the coal in the breasts is so worked as to match of the upper benches of coal, which acts as a temporary support roof, the coal in the arch being extracted when the pillars are robbed.

When the inclination of anthracite seams is less than 30°, the breast be opened with one chute in the center; which ends in a platform projinto the gangway, off which the coal can be readily loaded into the car. When this method is employed, the refuse is thrown to either a the chute. If the pillars are to be robbed by skipping or slabbing only, it is well to keep most of the refuse on one side. Sometimes, who top is good, and the breasts are driven wide, two chutes are used, by cost of making the second chute is considerable and is therefor advisable unless necessitated by the method of ventilation employed.

advisable unless necessitated by the method of ventilation employed.

Col. Brown's Method.—Fig. 23 shows a panel system devised by Col. Brown, of Lost Creek, Pa., which gives good results in thick seams pit from 15° to 45°, where the top is brittle, the coal free, and the mine ga Rooms or breasts are turned off the gangway in pairs, at intervals of

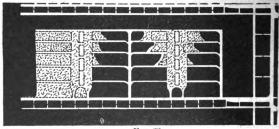


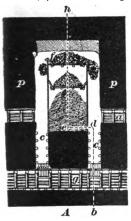
Fig. 23.

60 yd. The breasts are about 8 yd. wide, and the pillar between about wide, which is drawn back as soon as the breasts reach the airway nee level above. In the middle of each large pillar between the several pe breasts, chutes about 4 yd. wide are driven from the gangway up to airway above. These are provided with a traveling way on one side, go the miners free access to the workings. Small headings are driven bottom bench of coal, at right angles to these chutes, and about 10 or apart. These headings are continued on either side of the chutes until intersect the breasts. When the chute and headings are finished, the of getting the coal in the panel is begun by going to the end of the unost heading and widening it out on the rise side until the airway ab reached and a working face oblique to the heading is formed. This fit then drawn back to the chute in the middle of the panel. After the rise face in the uppermost section has been drawn back some 10 or 12 work in the next section below is begun, and so on down to the gang working the various sections in the descending order. Both sides of illar are worked similarly and at the same time toward the chute.

Small cars or buggies, are used to convey the coal from the working along the headings to the chute, where it is run down to the gangway be and loaded into the regular mine cars. This system affords a great degrafety to the workmen, because whenever any signs of a fall of roof or occur, the men can reach the heading in a very few seconds am perfectly safe. A great deal of narrow work must be done before any

Quantity of coal can be produced. The breasts are driven in pairs and at intervals, to get a fair quantity of coal while the narrow work is being done, and they are not an essential part of the system. It is claimed that the facility and cheapness with which the coal can be mined, handled, and cleaned in the mine more than counterbalance the extra expense for the narrow work.

Battery Working.—Fig. 24 shows a method of opening a breast by two chutes c, c, when there is a great amount of refuse, or when a great amount



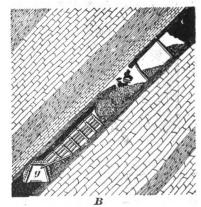


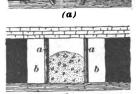
Fig. 24.

of gas is given off. The chutes are extended up along the rib to within a few feet of the working face, either by planking carried on upright posts, or by building a jugular manway, as shown in the sections (a) and (b), Fig. 25. These chutes, built of jugulars or inclined props and faced by 2" plank, are made as nearly air-tight as possible, to carry the air from the heading a to the working face. Fig. 24 shows a breast on a nitch ten steam to make the

made as nearly air-tight as possible, to carry the air from the heading a to the working face. Fig. 24 shows a breast on a pitch too steep to enable the miner to keep up to the face. In seams of less than 35°, the platform f shown near the face of the breast is unnecessary, and in seams thicker than 12 ft. it cannot be built; hence, this method of working is applicable (1) to beds pitching more than 35°, and (2) to thin seams

and (2) to thin seams.

The coal is separated from the refuse on the platform f, and is run down the manway chutes and loaded into the cars from a platform projecting into the gangway g. The refuse is thrown in the middle of the breast behind the platform. A certain amount of coal is kept on the platform to deaden the blow from the falling coal. The chutes are timbered when the character of the coal requires it. This plan can also be employed in thick seams having a heavy dlp, if there is enough

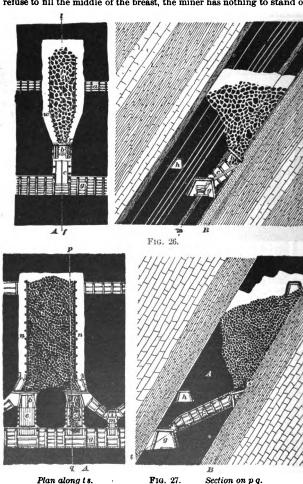


(b) Fig. 25.

refuse to fill the center of the breast so that the miner can work without the platform.

Fig. 25 (a) is a section through p, p when jugulars a, a are used to form the manways b, b along the sides of the breast; and (b) is a section through the

same line when upright posts a, a are used to support the plank in fo the manways b, b. The refuse in these cases only partially fills the In working very thick seams on heavy dips, where there is not errefuse to fill the middle of the breast, the miner has nothing to stand of



platform being impracticable; therefore, it is necessary to leave the coal in the breast. Loose coal occupies from 50% to 90% more space than in the solid. This surplus is drawn out through a central chute. If the

is poor, the movement of the coal will not in this way cause it to fall and mix with the coal; and if the floor is soft, the jugulars, which are stepped into the floor, are not so liable to be unseated, closing the manway and blocking the ventilation. The surplus is sometimes sent down the manways, leaving the loose coal in the center of the breast undisturbed, until the limit is reached

Single-Chute Battery.—To prevent the coal from running out through the chutes, the opening into the breast is closed by a battery constructed by laying heavy logs across the openings, as shown at b, Fig. 26, or else built on props, as shown at b, Fig. 27; a hole is left in the center, or at one side of the battery, through which the coal may be drawn. The battery closes all the openings into the breast, except the space occupied by the jugular manways,

and is made air-tight, or as nearly so as possible, by a covering of plank. Fig. 26 is a plan and section of a breast opened up by a single chute. The plan A is taken on the line mn shown on the section B, which section is taken on the line f is hown on the plan A. The pitch is great and the seam is so thick that the breast must be kept full of loose coal for the men to work upon, the surplus being drawn off at the battery b and run into the car standing on the gangway g through the chute c. A manway w is made along each side of the breast, for

the purpose of ventilation and affording a passage for the men to reach the working face. The heading a is used for an air-course between breasts. The main airway h is driven over the gangway g, where it will be well protected.

By drawing the surplus coal through a central chute, the manways are not injured so much as when it is drawn off through side chutes, as the coal will move principally along the middle of the breast. When the breast is worked up to its limit, all the loose coal is run out of the breast and the drawing back of the pillars is commenced. unless for some purpose they are allowed to stand for a time.

Double-Chute Battery.-Fig. 27 shows a plan and section of double-chute breasts used in very thick seams having a heavy The breasts are entered by

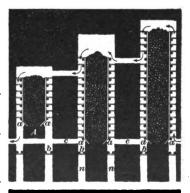


Fig. 28.

two main coal chutes c, c, each of which is provided with a battery b, through which the coal is drawn. A manway chute m is driven up through the middle of the pillar for a few yards and is then branched in both directions until each branch (slant chute) intersects the foot of a breast near the battery b, as shown. The jugular manways n, n are started at this point and continued up each side of the breast. The main airway h is driven in the solid through the sump A above the gangway. By driving the main gangway g against the roof, as shown, the pitch of the chute is lessened, and the loading chute cis more readily controlled

When the main gangway is not driven against the roof, a gate is placed in the chute below the check-battery, which enables the loader to properly handle the coal. Coal in excess of the amount necessary to keep the miner up to the face may be drawn through the main battery, or sent down the manway chute, from which it is loaded through an air-tight check-battery.

The main chutes are usually 8 or 9 ft. wide, but sometimes only for the st 6 or 8 ft.; above this they are driven about 6 ft. square. The manway first 6 or 8 ft.; above this they are driven about 6 ft. square.

and slant chutes are also about 6 ft. square.

When the seam is not thick enough to carry the return airway h (Fig. 27) over the gangway, the chutes are driven up in the same manner as in Fig. 27, for a distance of about 30 ft., where they intersect the airway. breast is opened out just above the airway, a battery being built in the airway immediately above each chute. A manway is driven from the ga up through the middle of the stump until it intersects the airway, trap door is placed at this point to confine the air. This manway i about 4 ft. × 6 ft., or smaller.

Fig. 28 shows a less complicated plan than Fig. 27. The main chut are driven up to the heading c, from which the breast is opened out

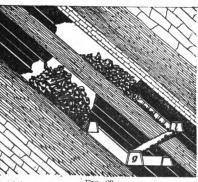


FIG. 29.

battery is built at 1 of each chute at the The marked a, a. are used for drawin battery coal, and ceiving the manway and are also used for eling ways. A chec tery b is placed in the to prevent the air-c from taking a sho from the gangway th the chute to the brea ways. This check-b is of great assistance loader when the chu a very steep pitch, can readily control th of coal through the hole.

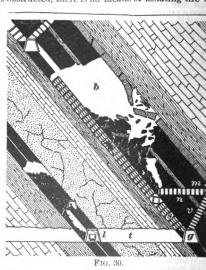
All these method open to the objection in case of any accide the breast manway the flow of which

shown by the arrows, is obstructed, there is no means of isolating the in which the accident occurs, and the ventilation of all the breasts beyond it is entirely stopped. To overcome this, sometimes the pillar A, shown in lefthand breast, Fig. 28, is left in each breast to protect the airway.

Rock-Chute Mining. Fig. 29 shows a section of two seams, separated by a few yards of rock. Chutes from 41 to 7 ft. high and 7 to 12 ft. wide are driven in the rock from the gangway or level g to the level l in the seam above, at such an angle that the coal will gravitate from the upper seam into the gangway q. The working, otherwise, is similar to that previously described.

Rock-chute mining contemplates the following sequence of operation:

1. The opening of all gangways and airlying a few feet above it.



ways in the lower seam, to develop coal as yet untouched in a thick s

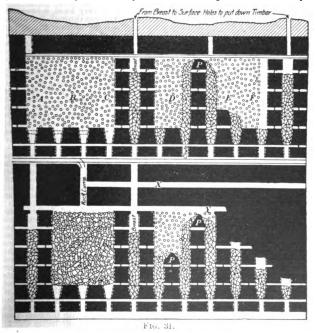
Developing the thick bed by a regular series of rock chutes driven 2. Developing the thick bed by a regular series of rock chuks driven om the gangway below; workings being opened out from chutes as in adinary pillar-and-breast working—the panel system or some other plan nay be found better than pillar-and-breast workings.

3. Driving the breasts to the limit of the lift and robbing out the pillars from a group of breasts as soon as possible, even if a localized crush is induced.

4. After one group of breasts is taken out and the roof has settled, opening a second series of chutes for the recovery of coal from any large pillars that were not taken out when the crush closed the workings.

5. While the work of recovering the pillar coal is in progress, a second group of breasts may be worked, and the process continued until all the area to be worked from that gangway has been exhausted. The same process is employed in opening lower lifts.

6. When all the upper bed of coal has been exhausted, the lower seam may be worked by the ordinary method. Workings in this seam may be



carried on simultaneously with the upper bed, but to avoid the possibility of a squeeze destroying these workings, very large pillars must be left.

After exhausting the upper seam, these pillars may be advantageously worked by opening one or two breasts in the center of each, and when these are worked to the upper limit, attacking the thin rib on each side, commencing at the top and drawing back.

When the roof of the lower bed is good, the cost of timbering and keeping open the gangways and airways will be considerably less than if these were driven in the upper seam, and this difference, in some cases, may be sufficient to pay for driving all the rock chutes.

There are three undetermined points in this connection, viz.: (1) The

maximum distance between the two beds, or the length of rock chut can be driven with satisfactory financial results. (2) The maximum of which such working can be successfully opened. (3) The maximum ness of the upper and also of the lower seam, which will yield results ranting the additional outlay when rock chutes are of considerable len

Fig. 30 shows how one or more seams are worked by connecting the a "stone drift," or "tunnel," driven horizontally across the mean through which the coal from the adjacent seams is taken to the hau way leading to the landing at the foot of the slope or shaft. Tunne sometimes driven horizontally through the measures from the surface.

to cut one or more seams above water level.

to cut one or more seams above water level. The lower seam of coal is worked from a gangway or level l, connot by a tunnel, or stone drift t, to the level or gangway g, in the seam. The stone drift may be extended right and left to open seams and below the thick seam. This tunnel, or stone drift, is never driven us breast in the upper seam, but directly under the middle of the pillar. In the upper and thicker seam, when the coal is very hard, a breast worked to the limit and the loose coal nearly all run out through the chinto the gangway g. The "monkey gangway" m is driven near the top return airway, and is connected to the upper end of the chute s by a heading n, and to the main gangway g by a heading v. These heading driven for the purpose of ventilation and to provide access to the batte case the chute s should be closed. In the lower seam, the breast is still the

case the chute s should be closed. In the lower seam, the breast is still be worked upwards in the ordinary way.

The J. L. Williams method of working anthracite, Fig. 31, has been app successfully by the originator at the Richards Mine, Mt. Carmel, Pa., an it 90% of the available coal is said to have been obtained. The method is a lower of the available with the bull worked distinction of the available with the bull worked distinction. lar-and-stall method with the following distinguishing points: (a) Timbe the gob with props set not more than 6 ft. apart, to keep up the roof du the extraction of the pillars. (b) Making holes from the crop, for delivery of timber into the workings. (c) Removing the pillars in sh lifts than is possible when the roof is supported with culm pillars. (d) King the gob open with timber for dumping the fallen rock, that would I to be sent to the surface if the breasts were flushed.

Both the floor and the roof of the mine were weak, so that it was possible to make either the breasts or the pillars wide. In some cases floor consisted of 3 ft. of clod, and to prevent its lifting and sliding, e alternate prop was put through the clod and its foot set in the slate bene while the other props were set on pieces of 2' plank 2 ft. in length to 1 down the bottom. A small gangway Xis driven to take out the chain pi and Y is a small gangway for taking in timber.

Running of Cosl.—In large seams, when the coal is soft and shelly or pery, and lies at an angle of more than 50°, and generates large quantitified amp, a danger to be guarded against is the sudden liberation of should a breast run; that is, should the coal at the face loosen and run by its own gravity, only stopping when it chokes or fills up the open shellow. To meet these conditions, the air-course may be driven above gangway and used as a return, the fan being attached as an exhaust, the working breasts ventilated in pairs. The inside manway of one of a of breasts is connected with the gangway for the intake, and the out manway of the other breast with the return airway, giving each pai breasts a separate split of the current. In collieries where this syster preasts a separate spint of the current. In collieries where this system working is followed, the coal is soft. A new breast is worked up a few ya but as soon as it is opened out, the coal runs freely and the manways pushed up on each side as rapidly as possible, to keep up with the face. The miners, one on either side, sometimes finish a breast without being able cross to each other. The work is done exclusively with safety lamps, when a breast "runs" the gas is liberated in such quantities tha frequently fills breasts from the top to the airway before the men can down the manway on the return side. When the gas reaches the cross-hit resses into the return sizway without reaching any part where men it passes into the return airway without reaching any part where men working. Should a run of coal block a breast by closing the manwa; affects the current of one pair of breasts alone. As the gangway is intake, leakage at the batteries passes into the breasts, as the cross-holes above their level and the gas is thus kept above the starter when at draw-hole. The gangway, chutes, and airway are supplied by woo pipes, which connect with a door behind the inside chute. If a breast r up to the surface, it does not affect the return airway, as it is in the solid.

Among the disadvantages urged against this system of working are the ollowing

It increases the friction, as the air must pass in the airway all the distance rom the breast to the fan, the area of the airway being small in comparison

o the gangway or intake.

As the faces of the breasts are so much higher than the return airway, he lighter gas must be forced down into the return against the buoyant

power of its smaller specific gravity.

The reduction of friction obtained by splitting is neutralized by each split running up one small manway and down another; the advantage of running through several pillar headings and thus securing a shorter course being lost. This can be partly obviated by ventilating the breasts in groups, but

the dangers avoided in splitting are increased. Blackdamp, which accumulates in the empty or partly empty breasts, works its way down and mixes with the intake current, as there is no return

current in the breast strong enough to carry it away, the return being closed

in the airway. All things considered, when the seam is soft and has a pitch of 40° and

All things considered, when the seam is soft and has a pitch of 40 and upwards, and emits large quantities of gas in sudden outbursts, as in running breasts, this system is the best that can be adopted.

When the Cosl is Hard and Gas is Not Fresly Evolved.—The reverse of the system just described is followed at some collieries where the coal is hard and but little gas is encountered. The airway is driven over the gangway or against the top, the fan being used to force the air inward to the end of the airway. The air is distributed as it returns, being held up at intervals by distributing doors placed along the gangway.

Among the advantages claimed for this plan are the following:

As the pressure is outward it forces smoke and gas out at any openings.

As the pressure is outward, it forces smoke and gas out at any openings that may exist from crop-hole falls or other causes.

The warm air from the interior of the mine returning up the hoisting

slope or shaft prevents it from freezing.

As the current is carried from the fan to the end of each lift without passing through working places, the opening of doors as cars are passing, etc. does not interfere with the current.

If a locomotive is used, the smoke and gases generated by it are carried away from the men toward the bottom. Locomotives are generally used

only from the main turnout to the bottom.

An objection to this system is that the gangway, as the return, is apt to be Starters and loaders are forced to work in more or less smoke, and even the mules work to disadvantage, while if gas is given off, it is passed

out over the lights of those working in the gangway.

However, in places where there is but little gas, and airways of large area can be driven, this plan works very satisfactorily, and some of the best ven-

tilated collieries are worked upon it.

tilated collieries are worked upon it.

An objection advanced by some against forcing fans is that they increase the pressure, thus damming the gas back in the strata. In case the speed of the fan is slacked off, the accumulated gas may respond to the lessened pressure and spring out in large volumes from its pent-up state. This argument, however, works both ways. An exhaust fan running at a given speed is taking off pressure, and if anything occurs to block the intake, the pressure is diminished, and the gas responds to the decrease on the same principle.

Hints for the Smaller Seams When They Are Small and Lie From Horizontal to About 10°.—Two gangways may be driven, the lower or main gangway being the intake. Branch gangways should then be driven diagonally or at a slant, with a panel or group of working places on each slant gangway. Large

with a panel or group of working places on each slant gangway. Large headings should connect the panels. In this system, the air is carried directly to the face of the gangway and up into the breasts, returning back through the working places. The intake and return are separated by a solid pillar, the only openings being the slant gangways on which are the panels.

The advantages of this plan are several:

The main gangway is solid, with the exception of the small cross-holes connecting with the gangway above; these furnish air to the gangway and are small and easily kept tight. These stoppings should be built of brick, and made strong enough to withstand concussion.

A full trip of wagons can be loaded and coupled in each panel or section without interfering with, or detaining the traffic on, the main road; one trip can be loaded while another is run out to the main gangway for transpor-

tation to the bottom.

The only break in the intake current is when a trip of cars is taken from, or returns to, a panel or section; this can be partially provided against by double doors, set far enough apart to permit one to close after the before the other is opened. This distance can be secured by opening first three breasts on a back switch above the road through the ganger pillar, or by running each branch over the other far enough to obtain distance for the double doors.

If it is not desired to carry the whole volume of air to the end of the way, a split can be made at each branch road. These will act as unequ splits in reducing friction, and, although not theoretically correct, are pref

able to dragging the whole current the full length of the workings.

The objections urged to this plan are that it involves too much expen in the large amount of narrow work at high prices necessary to open out colliery, that it necessitates a double track the whole length of the lift, at that the grade ascends into each panel or section. But the latter criticis falls, because the loss of power hauling the empty wagons up a slight grad is more than made up by the loaded wagons running down while the muk are away putting a trip into another panel or section.

For a large colliery this is without doubt the best and cheapest system.

When the Seam is Small and Lies at an Angle of More Than 10°.—In small seams lying at an angle of more than 10°, and too small to permit an airway over the chutes, it is more difficult to maintain ventilation. If air holes are put through every few breasts, and a fresh start obtained by closing the back holes, or if an opening can be gotten through to the last lift as often as the current becomes weak, an adequate amount of air can be maintained, because the lift worked can be used as the intake, and the abandoned lift above as the return. To ventilate fresh ground, the filling of the chutes with coal will have to be depended on, or a brattice must be carried along the gangway. This can be done for a limited distance only, as a brattice leaks too much air. As a rule, collieries worked on this plan are run along the gangway are run along the gangwa until the smoke accumulates and the ventilation becomes poor: then a new hole is run through and the brattice removed and used as before for the mext section. This operation is repeated until the lift is worked out. Sometimes, to make the chutes tight, canvas covers are put on the draw holes, the same usually left to the loaders to adjust, they are often very imperfectly applied. Then, as the coal is frequently very large, the air will leak through the batteries.

This plan works very satisfactorily if the openings are made at short intervals, say as frequent as every fifth breast, but the distance is usually much greater to save expense. As the power of the current decreases as the distance between the air holes is increased, good ventilation is entirely a

question of how often a cut-off is obtained.

An effective ventilation could be maintained in a small seam at a heavy angle by working with short lifts, say two lifts of 50 yd. instead of one of 100 yd., as at present. The gangways should be frequently connected, and one used as an intake and the other as a return. This would necessitate driving two gangways where one is now made to do, but the additional expense would be made up in the greater proportion of coal won.

FLUSHING OF CULM.

From 15\$ to 20\$ of the coal taken out of an anthracite mine, according to the methods used in the past, became so fine in the course of preparation through the breaker that it could not be used or sold, and had to be piled away as refuse. Recently, the coarser portions of these culm piles have been screened out and sold for use as steam sizes, while the finer part, together with the fine material from the breaker, has been carried back into the mines with water to fill the abandoned portions of the underground workings.

This culm is carried through a system of conveyors to the hopper, usually an old oil barrel, and the stream of water is conducted into the same hopper by a 3" pipe. The culm is then carried by the water through a pipe from 4 to 6 in. in diameter, which passes into the mine through the shaft, bore hole, or other opening, thence along the gangways to the chambers through the cross-cuts, and to the point where it is desired to deposit the culm. The bottoms or outlets of the chambers to be filled are closed by board partitions fitted closely, or by walls of slate or mine rubbish. The culm, as it issues from the end of the pipe, takes a very flat slope, and it is carried a long distance by the water, which ultimately filters through the deposited culm to the lower portion of the mine, to be pumped to the surface. When the chamber is filled to the roof, the pipe is withdrawn and extended to the next place to be filled, and so on. Wrought-iron pipe is said to be the best, next place to be filled, and so on. and the life of the pipe depends on the nature of the water used and the material treated. With fresh water and small culm from the buckwheat screen, it lasts 18 months; when carrying culm from the bank, ranging from dust to pea coal and some chestnut, 9 months; and when mixed with ashes, 6 months. The smaller the material the better.

The amount of water used depends on the distance to which the culm is

carried and the slope of the pipe.

From 11 to 11 lb. of water is required to flush 1 lb. of culm to level and down-hill places; 3 to 6 lb. of water to 1 lb. of culm to flush up-hill for heights varying from 10 to 100 ft. above the level of the shaft bottom. varying from 10 to 100 it. shows the level of the shall bottom. Any extensive varion of the pipe very materially increases the amount of water necessary.

Mr. James B. Davis, superintendent of the Dodson and Black Diamond mines, has ascertained by experiment that I cu. ft. of anthractic coal ground to culm can be flushed into a space of nearly 1½ cu. ft., and it is therefore impossible to compress the culm more than one-third. In addition to acting the property assured and emphasize the present accuracy and emphasize the as a filling and a support, to prevent squeezes and crushing, flushing has been advantageously used for fighting and sealing off mine fires. No instance has been recorded where spontaneous combustion has taken place in the flushed culm

The Dodson culm plant, which was a pioneer, cost \$7,473.42, with the capacity of flushing 119 tons per day, while the Black Diamond culm plant is capable of flushing 287 tons per day and cost \$6,280.12, but plants can probably be put up much more cheaply than this.

The saving from the flushing of culm over depositing it on the surface varies for the ordinary anthractic colliery from \$5 to \$15 per day. The average cost of putting in stoppings in a 9 vein is given by Mr. Davis as \$9.50, including material.

To remove the pillars after the intervening breasts have been filled with the focal of the pillars after the group is attacked and a read driven.

culm, the face of the pillar along the gangway is attacked, and a road driven up through the pillar, splitting it (z, Fig. 32). This road may be the full width of the pillar, but in general it is necessary to leave a narrow stump of coal on either side to keep up the fine flushed material in the adjoining

breasts. The thickness of this supporting coal depends entirely on the condition of the flushed material behind it. If that is fine, it will set firmly and form a compact mass that will not run. In such a case, the pillar may be entirely taken out, leaving a vertical wall of solidly packed flushed culm. the flushed material is of a size larger than buckwheat, it will not set compactly, but will run when it is opened up, and when such material fills the adjoining breasts, the thin pillar of coal must be left to keep back the culm. Timbers are placed flush up against the culm or the coal stumps, as the case may be, and if there is a tendency for the culm to run, lagging is placed behind the timbers. In some cases, as much as 700 ft. of timber have been used per 100 ft. of pillar taken out. As the pillar is removed, the top settles until it finally rests upon the flushed culm, and as the weight from the top and the pressure from the sides comes upon these props, they are broken, while the coal that has been left will also be crushed. At the Black Dia-



Fig. 32.

mond colliery, the props used are 16 ft. long, and at this colliery the top settles about 4 ft. if the flushed material is packed tightly before the roof pressure comes on it. After this settling, new props 12 ft. in length are put in close up against the culm and the broken stump of the original pillar, and they serve to keep the road open up to the working face.

METHODS OF MINING MINERAL DEPOSITS.

Much of what has already been given under the heading of Coal Minin applies equally to the mining of mineral deposits. It will therefore not b repeated under this heading, and the only methods here given will be thou

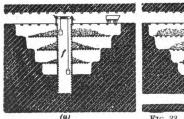
that have not already been covered.

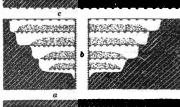
Highly inclined deposits are mined out as follows: Horizontal passages called drifts, levels, or galleries are driven through the ore at regular intervals. and connected by openings at right angles to the levels, which, in the case of perpendicular or highly inclined deposits, are called winzes or raises, according as they are sunk from above or raised from below. These parallel

according as they are sunk from above or raised from below. In ese paranea openings divide the ore body into a series of rectangles, thus serving to test its value. (See also Overhand-Stoping Method, page 304.)

Lavels.—The distance between the individual levels depends on the material being mined. They are placed nearer together in high-grade ore than in low-grade material. The width of the vein also has considerable influence on the distance between the levels. In veins where it is necessary to break into walls to afford working room in the levels, they are usually placed as far apart as is consistent with the economical handling of the material in chutes and convenient access to the working faces of the stopes. material in chutes and convenient access to the working faces of the stopes. The distance between the levels varies from 60 to 100 ft., and should be measured on the dip and not perpendicularly.

Winzes or Raises.—The distance between the raises or winzes varies from 30 to 250 ft., depending largely on the character of the material and the





(b) FIG. 33.

method of getting it into the chutes or winzes. Where the material at the working faces is shoveled or thrown directly into the chutes, they are often placed as close as 30 ft., while if the material is carried from the working face to the chute or winze in a wheelbarrow, the chutes may be much farther apart.

Stoping.—For narrow deposits, there are two general styles of stoping in regular use, called, respectively, underhand and overhand stoping. There are

several minor divisions under each.

Underhand stoping may be conveniently divided into underhand regular

and underhand Cornish.

The regular method of underhand stoping is illustrated in (a), Fig. 33, and may be described as follows: The miner selects a place in any given level or on the surface of the ore deposit from which to commence stoping. A cut 6 or 7 ft. in depth and from 6 to 8 ft. in length is made. This forms the first, or No. 1, bench in the stope. After this, he continues the work in each direction, supporting the track, if any exists above, upon stulls or timbering. After this No. 1 bench has proceeded a sufficient distance, he starts a similar cut in the bottom of it, which forms No. 2 bench, and is driven in both directions as before. At first the ore can be shoveled to the level above, but after considerable depth has been attained, it will be necessary to provide a winze, as shown at f, through which the ore from the lower benches can be holsted. Stulls covered with lagging are placed across the stope behind each bench as platforms, to support the waste material. Under hand stoping by the Cornish system is illustrated in (b), Fig. 33, and differs from the system just described only in that the level below has to be driven first, and a winze sunk to it. a is the lower level, b the winze, and c the upper level. The work is then carried on in successive benches, as described.

The advantages of the Cornish method are that any water that collects in the stope flows to the lower level and does not have to be taken care of in each individual stope. Also, the ore can be tumbled down through the raise to the lower level, thus avoiding the extra hoisting with a windlass, or small hoist.

The advantages that apply to any system of underhand stoping are as follows: The ore can be extracted at once; while the stope is new, the miner is protected from the roof by stulls and stagings; the loss of fine and valuable mineral is reduced, owing to the opportunity for sorting afforded during the

handling of the broken ore.

The disadvantages are as follows: The manner in which the ore must be handled is expensive; an individual pumping plant will be necessary in each stope of a wet mine with the regular system; should the mine be abandoned for any length of time, the stulls become loose and allow the rock stowed upon them to fall on the face of the ore, rendering the mine unsafe, and burying the ore so as to require a large expenditure of time and money to reopen the workings; in a wet stope, the water flows down over the working faces, interfering with the workmen and forcing them to stand continually in water.

Overhand Stoping.-In this system of stoping, the ore is broken down from above as the work progresses. Work is usually started from the bottom of a raise, as B, Fig. 34. After the lower level A has been driven, the miner stands on top of the lagging over the caps and works out a slice C 5 or 6 ft. high, this being followed by succeeding slices, as D and E. timbered or cribbed at intervals, through which the material may be thrown down and any waste packed in the space between the chutes, as at F. In cases where the entire deposit is of value, a portion of the broken ore is allowed to accumulate as a platform upon which the men stand while

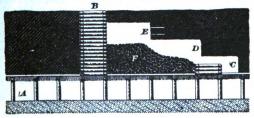


Fig. 34.

working, only enough being sent through the chutes to provide working

worsing, only enough being sent inrough the chutes to provide working room. After overhand stoping is started, the work may be carried on by means of breast holes, as shown at E. The force of gravity assists in breaking the rock, and reduces the powder necessary for blasting.

Where rich ore is broken, platforms of planks, or sheets of canvas or bull hide covered with plank, may be placed over the filling to receive the broken ore, thus preventing the loss of fine and valuable material in the filling. One argument which is usually presented against overhand stoping is that the roof is not secured by timbering, but this is offset by the fact that the workmen are always close to the roof and thus examine its condition and break off any dangerous portions or give them such support as may be break off any dangerous portions or give them such support as may be needed with temporary timbers.

Overhand stoping may be carried on in a number of modified forms, all of which involve the principle of breaking down the material in such a manner that the work is aided by gravitation. Sometimes, where practically the entire deposit is removed, temporary platforms supported on stulls are constructed close to the working face for the workmen.

The advantages of overhand stoping are that no hoisting or pumping is required in the block of ore being worked, as with underhand stoping without a winze; water gives no trouble in the stopes; less timbering is required than in the underhand stoping, because no platforms are required to store waste, and the timbering in working stagings is usually recovered; where the mine is abandoned for a time, the working face is usually left in better

shape with overhand than with underhand stoping. In the overhand system,

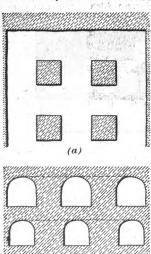
gravity assists in the breaking of the ore.

The disadvantages are that the miner is forced to work under an unsupported roof, though the fact that he is close to it enables him to examine and take care of any dangerous portions. There may be greater loss of the fine and valuable material that becomes mixed with the waste than in underhand stoping, though this may be largely prevented by the use of boards or canvas.

Flat or Slightly Inclined Deposits.—Where flat or slightly inclined ore bodies are being worked, the working drifts (corresponding to levels in steeper deposits) are driven comparatively close together (about 30 ft. apart) and the material between them removed in successive steps, as in underhand or overhand stoping, the space behind the miner being packed with waste material to support the roof, or the roof being supported by timbering until the ore is removed. Sometimes pillars of ore have to be left to aid in the support of the roof, and when this is the case, the miners try to leave the pillars where the ore is low grade. When a deposit of ore is of uniform value throughout, and the roof of a somewhat flexible character, it may be lest down without much, if any, stowing, as in the longwall system of coal mining. In other cases, the material is removed like square work or by pillars and rooms, the pillars in either case being robbed as closely as possible before leaving the workings.

LARGE DEPOSITS OVER & FEET THICK.

With a deposit much over 8 ft. in thickness, it is impossible to keep the



(b) Fig. 35.

thickness, it is impossible to keep the walls in place by stulls or single sticks of timber. Large masses of mineral frequently contain very valuable material, and engineers have developed a number of methods for the removal of their valuable contents. The method depends largely on the value per ton of the material being removed and local conditions as to the cost of labor, timber, filling material, character of wall rock, etc. The methods used for these deposits are square work, filling, caving, and square-set timbering

systems.

Square work, also called the chamber-and-pillar system, is illustrated in Fig. 35. Galleries are driven through the ore as shown, the deeper galleries being smaller than the upper ones, the object being to leave larger pillars for the support of the material above the workings. Galleries are then driven at right angles to these, to leave square pillars, as shown. When this square pillars, as shown. When this system is applied to a bed that is only 30 or 40 ft. thick, from three-fourths to eight-ninths of all the material in the deposit can be removed, the remainder being left as pillars; but where it becomes necessary to leave floors be-tween the succeeding levels, as shown in (b), Fig. 35, scarcely one-half of the deposit can be removed, even when it is of such a firm nature that the galleries can be driven considerably wider than the thickness of the pil-This system of mining is applied to the removal of salt, gypsum, build-ing stone, and various low-grade ores, and is very similar to the room-andpillar system (see page 280)

The advantages are that it requires no timbering, and that, owing to the

arger size of the chambers, the material can be removed at a low cost per The disadvantages are that a large portion of the deposit has to be left on. antouched, and that where the formation being mined is at all soft, it is not safe to work these large chambers.

Filling Methods.—Sometimes a filling of worthless material is substituted for the worked-out ore. This system may be carried on by any one of a

number of different plans.

Slicing Method.—In some cases, comparatively small drifts or chambers (from 6 ft. \times 6 ft. to 10 ft. \times 10 ft.) are driven through the ore across the deposit, and then tightly packed with broken rock, after which other drifts or chambers are driven beside the first ones and also packed or filled. This process is continued until a slice has been removed from under the entire deposit. The process is then repeated on top of the filling, taking out successive chambers and filling them, until another slice has been removed. This method has been used in the copper mines of Spain, and has also been tried at some mines in the United States with varying degrees of success,

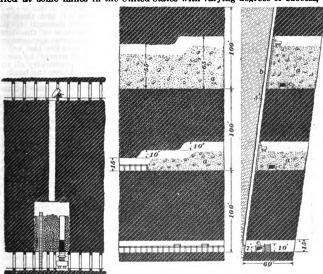


FIG. 36.

Fig. 37.

depending principally on the cost of the stowing material compared with the value per ton of the deposit being removed. In this process, the filling material should be composed entirely of large pieces, so that it can be packed closely.

Transverse Rooming With Filling.—In other cases, a filling system is used in which rooms or chambers are driven across the deposit and then continued upwards by overhand stoping, the ore being thrown to a lower level through a chute cribbed up as the work progresses, and the excavated space, filled up with broken rock brought down through a chute from above, as shown in Fig. 36. After the rooms are worked out between two levels, the pillars are removed in the same manner.

Longitudinal Back Stoping With Filling.—In this case, the deposit is worked as a series of overhand stopes, Fig. 37, the space below the workmen being filled with broken rock a brought down through raises b from above, the ore being thrown to a level c, which has been timbered through the filling material on

the first or lower floor of the stope. This method has been very successful applied to some of the large iron mines of the Lake Superior region of

United States.

The filling material used in any one of the various filling methods may obtained at the surface, may be partially or wholly obtained from the warrock associated with the vein material and from drifts or passages that have to be driven in barren ground, or it may be obtained by driving drifts in the hanging wall, and opening chambers there, from which the waste may be obtained. (See also Flushing of Culm, page 314.)

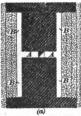
Caving Methods.—The longwall method of mining coal is really a caving

Caving Methods.—The longwall method of mining coal is really a cavin system, but where this system is applied to the mining of large masses, becomes necessary to introduce some special features. There are two general systems in use, caving a back of ore and caving the gob or waste only.

becomes necessary to introduce some special features. There are two general systems in use, caving a back of ore and caving the gob or waste only.

Caving a Back of Ore.—In this system, drifts or levels are run through the ore a few feet below the top of the deposit, as though the material above were to be removed by overhand stoping, but in place of breaking the materis down, it is allowed to cave by gravity. When a back of ore is thick (20 for more), the entire stope is sometimes allowed to cave full and then the broken ore removed by driving heavily timbered drifts through to the farther side and drawing the crushed material into the face of the drift.

When the overlying worthless material appears, operations are continued by removing the last set the drift and drawing the ore from nearer the shaft.



When the overlying worthless material appears, operations are continued by removing the last set in the drift and drawing the ore from nearer the shaft. This method is continued until practically all the broken ore has been removed. Where the back of the ore is comparatively thin (less than 20 ft.), the caving is usually accomplished at the face of the drift only, the drift being driven a short distance beyond the timbering without support. The ore above this unsupported portion will cave in and can be removed. When the waste rock and old timber from above appear, the operator retreats, removing one set of timber from the drift, caving and removing the ore over it. In this

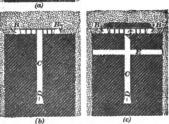


Fig. 38.

ing the ore over it. In this manner, operations are continued until all the ore over the drift or stope has been caved, when another drift or stope is driven beside the first and the ore over it caved. In this method, blasting has to be resorted to only in driving the drifts, from one-half to three-fourths of the ore being obtained without the use of powder.

The advantages of this system are that little blasting is required; practically the entire deposit is recovered; the mining cost per ton is very low.

.The disadvantages are that the ore is liable to become

mixed with more or less dirt, which caves down with it; only one level of the mine can be operated at a time, and the surface of the ground is allowed to cave into the openings thus rendering it unfit for ordinary surface uses.

cave into the openings, thus rendering it unfit for ordinary surface uses.

Caving the Waste Only.—In this system, Fig. 38, drifts A and galleries are driven through the top of the ore body immediately under the waste rock. After one of these drifts or galleries is completed, the floor is covered with a lagging of plank or poles, and the waste material allowed to cave on to this platform. Subsequently, other drifts are driven beside the first one, the floor covered with lagging, and the waste allowed to cave. This process is continued until a slice has been removed over the entire surface of the ore deposit, when more drifts are driven lower down and another slice removed. After the first slice has been removed, the broken or waste material is supported on the lagging laid on the floors of the first drifts, and hence the miners have only to support this lagging in order to support the waste. The caving of any individual drift crushes the ore on either side to a considerable extent, thus materially reducing the blasting expense.

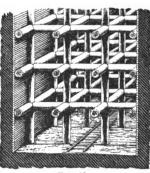
The advantages of this system are that the entire deposit is recovered; Little blasting is required; the ore obtained is clean; the mining expense is comparatively low per ton.

The disadvantages are that only one level of a mine can be producing at a time; the surface is allowed to cave, thus rendering it unfit for surface uses.

SQUARE-SET SYSTEM.

Frequently, large masses of material are encountered, which it is necessary to remove, and at the same time support the surrounding material.

At times, it is not desirable to fill the stope while the ore is being removed, and, at the same time, it is impossible to support the walls by single sticks or stulls. To overcome these difficulties, the square-set system has been evolved, which consists in the supporting of the walls by means of a series of square frames, from 6 to 9 ft. square, which are placed in position as fast as the ore is removed. The use of these frames reduces the length of the individual sticks, and so produces a firm structure. The timbers may be square-sawed material or round logs. If the walls are soft, the sides and top may require lagging, and if the floor is soft or composed of ore, sills will be necessary under the posts. The mining is carried on by overhandstoping system, removing one block at a time and replacing it with the square set. Fig. 39 represents a stope, the walls and roof of which are supported by square sets that are lagged from the outside. In this case, the square sets are made from round timber.



IRREGULAR DEPOSITS.

Coyoting, or Cophering.—Bodies of valuable material frequently occur that cannot be mined by any regular system. These are recovered by simply following the ore throughout its irregularities and removing it with the use of as little supporting timber or other material as possible. Owing to the crooked and irregular passages that occur in such mines, the work has been called coyoting, or gophering. Sometimes regular levels are driven at stated intervals, and the coyoting, or gophering, carried on from them. Many of the small gold and silver mines of the West, the mines of Mexico and South America, and the Missouri lead and zinc deposits are worked by this system, the object being to remove as much of the ore as possible without the use of

the object being to remove as much of the ore as possible without the use of timbering or the driving of unnecessary passages.

Probably one of the best examples of working irregular deposits is the mining practice in the Joplin zinc district, Missouri. The deposits of zinc blende are irregularly distributed through a limestone rock, and the mining is carried on in a very crude and irregular fashion.

After an ore body has been found by drilling, a shaft 5 ft. × 5 ft. to 6 ft. ×

9 ft. in the clear is sunk by the contractor, the price being \$4 per foot for soft and \$9 per foot for hard ground for the first 50 to 80 ft., the contractor doing all the work in sinking and timbering. Through the soft ground, the shaft is timbered by 4'' round poles or by $2'' \times 4''$ or $2'' \times 6''$ timbers laid flatwise, skin to skin. The mines are divided into four kinds. (1) Very hard mines that require all the ore to be drilled with air drills and blasted out, and (2) Mines that are hard but have open crevices require no timbering. between the strata where a hand drill can be driven and a charge of dynamite lodged and exploded, throwing down a large amount of dirt and so jarring the surrounding ground that it may be easily cut down with the miner's pick. This kind of ground needs no timber. (3) Mines that are moderately soft and where the miner can place a blast anywhere by driving a spud, throwing down a large amount of ore. The drifts are car in the sets of timber and laggings to hold the roof. (4) Mines that are soft and where a drift cannot be carried over $8 \text{ ft.} \times 10 \text{ ft.}$ in size, where getting of the ore is all performed by pick and shovel, and where it is no sary to timber close and drive spiling overhead as well as along the st and to resort to mud-sills in the floor of the drift.

When the shaft reaches the ore and the drift is extended for some tance to prove the ore body, underhand stoping is used and 15' are drilled by hand in the bottom. A charge of 50 lb. of 40% dynamite life stope 10 ft. × 10 ft. The cost of 75 tons of ore, hoisting it and dumping it the mill platform during a shift of 9 hours in the two classes of hard mi

mentioned, is, according to Mr. E. Hedburg, as follows:

ground boss	\$ 2
2 miners at \$2.00	
2 miners at \$2.00	
2 shovelers at \$1.75	
hoister	1.
l engineer, who also sharpens picks and drills	2.
l engineer	
Dynamite	6.
Fuel	
Oil and supplies	
Superintendent	
Total	\$33.

Or 44.5 cents per ton of rough ore; this includes pumping the mine. In very soft ground, a drift 8 ft. to 10 ft. high is driven, a spiling put in the top and sides. When one level is worked out, the whole drift is then caved from the surface and allowed to settle down on the floor of timbers. The cost of mining in soft ground is about the same as in hard ore, as the saving of labor and dynamite is expended in timber and time. A typical primitive mining plant in this region, which has a shaft 150 ft. deep, with pump, hoisting engines, and bollers, and including hand jigs, screens, and tools, costs from \$2,000 to \$3,000; more modern plants are however now being erected, costing \$8,000 to \$10,000.

SPECIAL METHODS.

Frozen Ground.-When the material of placer deposits is frozen, as in Alaska and Siberia, it is mined by building a fire on the surface, which thaws the earth to a depth of from 1 ft. to 14 in. The embers are then scraped away and the thawed material removed. By repeating this operation, a shaft can be sunk, and then, by building a fire against one side, a drift can be started and continued by thawing the face, I ft. at a time. It has been found that 1 ft. of timber piled against the face of a drift will thaw to a depth of about 1 ft., but that 14 in is practically the maximum depth to which any ordinary fire will thaw the material. The openings have to be securely, but not heavily, timbered.

Lesching Methods.—Salt, copper, and sulphur have been mined by leaching methods. In the case of salt, a hole is drilled into the salt formation, water allowed to flow down and dissolve the salt, and is then pumped out as a concentrated brine. For excavating upward in salt, a jet of water is made to play upon the roof of the level to be raised, and the resulting brine is carried

off in launders.

When old workings containing the sulphides of copper are left exposed to the action of air and to percolating waters, part of the copper is converted into soluble sulphate. Water pumped from such mines may be a profitable source of the metal, for by passing it over iron bars or scrap iron the copper will be separated and deposited as cement copper in the bottom of the vessel containing the iron.

In the case of sulphur, superheated steam is forced down to melt the

sulphur, which is then pumped out.

COSTS OF MINING ANTHRACITE.

The following costs include only labor and supplies, and do not include, n general, improvements, royalties, taxes, and other similar fixed charges hat are independent of the method of mining.

LEHIGH REGION (PENNA.).

The costs for the Lehigh region, though based on the results of a single company, are believed to be very fairly representative of the entire region. They are the mean costs of two collieries where about 2,000 men were employed inside and outside, and apply to the year 1897, when the condition at all anthracite mines was very unfavorable to economical working, as the mines were then working on very short time.

The tonnage at these collieries for the year was as follows:

				,		
January,	29,775.04	May,	34,090.02	September,	27,406.94	
February,		June,	35,761.89	October,	56,710.04	Total,
March,	42,827.04	July,	44,409.13	November,		463,672.08.
April,	38,553.08	August,	37,500.97	December,	37,587.02 J	

The following tables show the distribution of this output by sizes during the year, and the costs per ton itemized under the several headings given:

PERCENTAGES OF DIFFERENT SIZES.

Month.	Lump.	Broken.	Egg.	Stove.	Chestnut.	Pea.
January	10.56	23.59	18.27	18.69	14.21	14.68
February	12.34	22.54	18.11	17.98	14.50	14.53
March	11.85	19.26	18.81	19.69	13.18	17.21
April	12.81	19.21	18.35	19.48	11.14	19.01
May	13.81	19.11	18.35	19.01	11.32	18.40
June	15.29	18.60	17.73	19.08	11.23	18.07
July	14.26	19.89	17.41	18.30	11.25	18.89
August	13.56	20.26	18.10	17.72	11.49	18.87
September	12.31	20.41	18.27	18.28	11.61	19.12
October	12.21	18.01	19.15	18.89	12.28	19.46
November	11.40	18.53	19.78	19.79	12.01	18.49
December	10.78	19.56	20.09	20.32	12.07	17.18
Year	12.58	19.71	18.59	18.99	12.15	17.98

COSTS OF MINING AND PREPARATION.

Month.		Outside.			Inside.		Total	Credits.	Net Cos
Month.	Labor.	Supplies.	Total.	Labor.	Supplies.	Total.	Cost.	Creatis.	Net Cos
January	.300	.109	.409	.951	.196	1.147	1.595	.100	1.495
February	.297	.085	.382	.909	.190	1.099	1.519	.063	1.456
March	.243	.047	.290	.844	.151	.995	1.311	.088	1.223
April	.242	.071	.313	.822	.137	.959	1.303	.075	1.228
May	.251	.100	.351	.852	.166	1.018	1.397	.103	1.294
June	.300	.079	.379	.500	.203	.703	1.576	.103	1.473
July	.240	.063	.303	.487	.162	.649	1.485	.084	1.401
August	.248	.095	.343	.709	.182	.891	1.579	.085	1.494
September	.278	.096	.374	.682	.158	.840	1.588	.054	1.534
October	.228	.093	.321	.721	.129	.850	1.580	.072	1.508
November	.247	.093	.340	.806	.210	1.016	1.846	.091	1.755
December.	.290	.061	.351	.833	.220	1.053	1.883	.090	1.793
Year	.271	.092		1.109	.162	1.271	1.634	.088	1.546

COST PER TON OF SUPPLIES USED INSIDE,

Distribution.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.
Oils	.010	.011	.007	.010	.007	.009	.006
Powder	.036	.030	.031	.026	.030	.032	.029
Lumber	.007	.025	.011	.004	.002	.008	.007
Props	.040	.027	.021	.015	.022	.027	.019
Feed	.039	.018	.019	.017	.023	.022	.022
Mules killed, etc.	.010	.005	.014	.019	.013	.009	.015
T rails, frogs, etc	.005	.012	.007	.009	.018	.010	.010
Wire ropes General supplies	.019	.018	.016	.009	.018	.025	.013
Total general supplies	.166	.167	.140	.109	.133	.163	.134
Pumping machinery Hoisting machinery	.009	.005	.004	.012	.016	.023	.004
Ventilating machinery Boilers Mine cars Engines	.021	.018	.007	.016	.017	.017	.024
Total repairs	.030	.023	.011	.028	.033	.040	.028
Total cost inside	.196	.190	.151	.137	.166	.203	.162
Net cost inside	.096	.127	.063	.062	.063	.100	.078

COST PER TON OF SUPPLIES USED OUTSIDE.

Distribution.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.
Oils Lumber Feed Mules killed, etc.	.010 .022 .008	.008 .025 .004	.007 .003 .005	.006 .016 .004	.009 .015 .005	.009 .005 .005	.008 .012 .006
T rails, frogs, etc	.020	.021	.001	.003	.004	.005	.002
Total general supplies	.060	.058	.031	.037	.073	.040	.047
Pumping machinery Hoisting machinery Ventilating machinery Breaker machinery Boilers Breaker Tracks and sidings Miscellaneous	.001 .008 .028 .006 .006	.002 .012 .005 .008	.001 .008 .002 .005	.001 .014 .013 .006	.003 .017 .001 .005 .001	.008 .003 .011 .011	.001 .008 .005 .002
Total repairs	.049	.027	.016	.034	.027	.039	.016
Total cost outside	.109	.085	.047	.071	.100	.079	.063
Credits Net cost outside	.109	.085	.047	.071	.100	.079	.063

In the two tables above and the one following, the figures were available for seven months of the year only, but an average for these months gives a fair average for the year.

ITEMIZED COST OF OUTSIDE LABOR.

Occupations.	Jan.	Feb.	March.	April-	May.	June.	July.
oreman and assistants	.013	.012	.007	.006	.006	.006	.003
lerks, shipper and supply	.004	.004	.003	.003	.002	.002	.002
oisting engineers	.009	.022	.018	.021	.019	.026	.021
ump and fan engineers	.003	.008	.003	.002	.003	.003	
ocomotive engineers and helpers	.014	.014	.011	.009	.011	.013	.011
iremen and ashmen	.078	.071	.056	.060	.063	.069	.057
tablemen	.005	.005	.003	.008	.004	.005	.003
Vatchmen	.007	.006	.004	.005	.006	.006	.004
Total miscellaneous	.133	.137	.105	.109	.114	.130	.101
opmen and footmen	.004	.004	.002	.003	.003	.004	.003
Cop drivers and oilers	.007	.007	.006	.006	.007	.008	.007
Dumpmen	.002	.003	.002	.002	.002	,003	.002
Platform and docking boss	.014	.013	.013	.012	.012	.012	.012
Chute bosses	.006	.006	.005	.006	.005	.004	.006
Slate pickers	.059	.063	.058	.053	.048	.056	.057
Car loaders	.007	.007	.007	.006	.006	.008	.008
Breaker engineer	.003	.003	.002	.002	.002	.001	.002
Dirt and plane engineer	.007	.001	.001	.001	.001	.001	.001
Rock and dirt men	.007	.009	.009	.006	.004	.005	.005
General laborers	.012	.013	.009	.011	.020	.022	.012
Total breaker	.128	.129	.114	.108	.110	.124	.115
Pumping machinery	.001	,001					
Hoisting machinery	.010	.005	.005	.005	.006	.009	.005
Ventilating machinery	1	1	1	1	l	.003	
Breaker machinery	.005	.004	.004	.006	.003	.002	.002
Boilers	.004	.004	.001	1		.006	.002
Breakers	.007	.009	.007	.005	.011	.019	.006
Tracks and sidings	.008	.007	.007	.009	.007	.008	.007
Miscellaneous	.004	.001					.002
Total repairs	.039	.031	.024	.025	.027	.046	.024
Total cost outside labor	.300	.297	.243	.242	.251	.300	.240

WYOMING REGION (PENNA.).

The following tables of costs for the Wyoming region give mean results from a number of different collieries which are quite widely separated in location and at which the conditions of working are so different that the mean results given are thought to represent average results for the entire region. They also apply, approximately, to the Lackawanna Valley, where the general conditions are the same, although the seams are much nearer the surface than in the Wyoming region, and the amount of gas present in the coal is much less. These same figures are probably also fairly representative of the Schuylkill and Shamokin fields.

The collieries for which the following figures are averages are all operated through shafts, varying in depth from 350 to 1,100 ft., and many of the mines are extremely gaseous. The number includes several entirely new and modern surface and underground plants, and the others, though not new, have been overhauled and modernized as much as possible. At these collieries 10,000 men were employed during the year 1895, for which the data are given, and during the same year the output was 1,862,144 tons,

distributed during the year as follows:

Month.	Ton- nage.	Days Worked.	Month.	Ton- nage.	Days Worked.	Month.	Ton- náge.	Days Worked.
January .	107,952	7.94	May	179,752	11.92	September	161,213	11.52
February	98,109	7.37	June	164,062		October	198,161	13.90
March	141,991	9.95	July	145,445		November	228,433	17.15
April	136,375	9.69	August	177,241		December	123,406	8.87

PERCENTAGES OF DIFFERENT SIZES.

Month.	Lump.	Steamer.	Broken.	Egg.	Store.	Chestnut.	. 1
January	8.21	.02	17.53	20.31	21.46	18.04	1
February	8.29	.12	17.75	20.41	20.85	.17.44	. 1
March	6.20	.55	17.64	20.04	20.65	18.00	. 1
April	7.01	.38	16.76	20.17	20.92	18.12	1
May	4.79	.27	18.63	20.33	21.42	18.23	ī
June	3.29	.21	22.43	19.72	20.21	18.57	1
July	7.84	.42	19.42	19.54	19.46	18.58	1
August	5.05	.57	19.84	20.69	18.92	18.62	1
September	4.25	.27	18.81	21.98	19.98	19.32	ī
October	4.72	.01	16.77	22.00	21.27	19.88	ī
November	2.69	.16	15.56	22.42	22.66	20.71	ī
December	4.40	.57	14.03	22.62	21.27	21.41	i
Year	5.23	.29	17.96	20.95	20.80	19.03	. 1

COSTS OF MINING AND PREPARATION PER TON.

		Oute	ide.			Ins	side.		Cost.	, mi	
Months.	Labor.	Supplies.	Repairs.	Total.	Labor.	Supplies.	Repairs.	Total.	Total Cc	Credits.	
January February March April May June July August September October November December Vear	.363 .376 .297 .305 .270 .290 .309 .286 .284 .267 .262 .344 .297	.042 .042 .031 .034 .022 .032 .046 .030 .039 .036 .029 .045	.014 .014 .010 .023 .011 .019 .017 .012 .013 .010	.419 .432 .338 .362 .303 .333 .374 .333 .316 .301 .407	.984 .947 .872 .870 .839 .874 .879 .873 .890 .856 .954	.249 .273 .182 .203 .164 .206 .266 .194 .201 .188 .214 .307	.028 .030 .022 .020 .015 .018 .033 .026 .024 .020 .018 .028	1.211 1.250 1.076 1.093 1.018 1.098 1.178 1.093 1.115 1.064 1.092 1.289 1.118	1.630 1.682 1.414 1.455 1.321 1.431 1.552 1.426 1.450 1.390 1.393 1.696 1.463	.120 .104 .096 .103 .101 .105 .098 .102 .105 .100 .104 .120	

COAL PRODUCTION OF UNITED STATES.

	Bitumir	ious.	Anthra	cite.
Year.	Tons of 2,000 Lb.	Value.	Tons of 2,240 Lb.	Value.
1890	111,302,322	\$110,420,801	46,468,641	\$66,383,77
1895 1897	135,118,193 147,609,985	115,779,771 119,567,224	57,999,937 52,611,680	82,019,27 79,301,95
1898 1899	166,592,023 193,321,987	119,367,224 132,586,313 167,935,304	53,382,644 53,944,647	75,414,53 88,142,13

PRICES OF COAL.

The table on page 327, given by the U.S. Geological Survey, will be of int as showing the fluctuations in the average prices rulling in each State since Prior to that year, the statistics were not collected with sufficient accura make a statement of average prices of any practical value. These average obtained by dividing the total value by the total product, except for they 1886, 1887, and 1888, when the item of colliery consumption was not constant.

CHANGE OF CASE	XXX	1887	1888	088	250	68	26.5	202	807	830	.068	1001	TODO.	10001
State of Tellings.										1			1	
	01 40	00 10	101	11 10	61 00	101	20 10	00 00	60 00	00 00	00 00	80 00	80 TE	00 10
Mabama	41.40	00.14	01.10	11.10	97.00	41.07	41.00	20.33	40.30	40.30	20.00	40.00	40.10	41.00
\rkansas	T.60	1.68	00.1	1.42	1.29	1.19	1.24	1.34	1.22	1.20	17.1	1.00	1.03	1.1/
alifornia	3.00	3.00	4.00	2.36	2.56	2.20	2.46	2.31	2.31	2.33	b 2.35	6 2.55	b 2.53	62.68
Tolorado	9.35	2.50	5.50	151	1.40	1.37	1.62	1.94	1.94	1.20	1.16	117	115	110
Contraction	1.50	1.50	1.50	1.50	104	1.50	66	86	82	83	20	20	81	1 00
debe	2001	201	2014	2011		201			2	3		00 00	0 57	200
1ало	,	00		1	00			00	90	0	80	00.00	2.01	0.00
llinois	11.11	1.09	1.12	.97	.93	16:	.91	68.	68.	98.	98.	.72	.78	.85
ndiana	1.15	1.34	1.40	1.02	66.	1.03	1.08	1.07	96.	16.	.84	28.	.81	88.
ndian Territory	1.60	1 87	188	1 76	68	1 74	171	1 79	1.59	1.43	1.40	1.34	1 39	1 43
Target Letting J	1 95	1.94	1 20	1 22	1 94	1 97	1 20	1 20	1 96	1 90	117	1 18	1 14	1 04
UWB	300	10.7	201	1.00	100	100	1.00	7.00	000	000	17:7	1 10	100	17:1
Kansas	1.20	1.40	1.50	1.48	1.30	1.31	1.315	1.21	1.23	1.20	CI.I	1.18	1.09	1.16
entucky	1.15	1.15	1.20	66.	.92	.93	.92	98.	88.	98.	.78	.79	.79	.79
Maryland	95	95	95	98	.86	200	68	88	77	S	8	92	94	2.76
Tobicon	1 50	1 50	1 66	1	1 00	1 66	1 56	1 70	1 47	1 60	1 69	1 46	1 47	1 20
MICHIGAII	1.00	1.00	1.00	1.11	1.00	1.00	1.00	1.13	1.7	1.00	7.00	05.1	1.1	1.00
dissouri	1.30	1.34	2.21	1.36	1.24	1.23	1.23	1.23	1.17	1.12	1.08	1.08	1.07	1.20
Tontana	3.50	3.50	3.50	2.42	2.45	2.27	2.36	1.99	2.04	1.89	1.47	1.76	1.57	1.57
levada									3.15					
law Maxioo	3.00	3.00	3 00	1 79	1.34	1 68	1.69	1.47	1.57	1.49	1.49	1.38	1.35	1.39
Touth Concline	0000	00:0	00.0		1 7.4	1 00	1 11	1 50	1 76	1 66	1 50	1 9.4	1.05	1 20
ordi Caronna	,	1	01.0	9	1.1	1 40	1.1	1.00	110	1.00	000	1 00	1 11	110
vorth Dakota	1.09	00.1	9.50	1.43	1.40	1.40	06.	1.15	1.12	1.07	T.03	1.00	1.11	1.13
hio	.95	88.	.93	.93	76.	.94	.94	.92	.83	.79	.79	.78	86.	.87
)regon	2.50	2.20	3.00		5.89	3.00	4.29	3.57	3.87	3.36	5.30	3.09	3,65	3.00
ennsylvania bituminous	8	06	.95	77.	.84	.87	8.	08.	.74	.72	17.	69.	.67	.76
ennessee	1 15	1.30	1.10	1.91	1.10	1111	1.13	1.08	.97	.93	98.	.81	.77	88.
2000	100	00 6	9.05	99 6	9.53	9.40	68 6	86.6	9.39	1 88	1.65	1.52	1.66	15
toh	010	0000	010	1 50	1 74	180	1.56	1 48	1 40	131	1.00	1 19	1.07	1 97
Udil	1.00	2.00	1.00	00	1 1	69	98	84	24	63	89	67	209	69
mainta	1.00	# . · ·	1.00	06.	21.0	30.0	000	1000	00.0	00.0	00.0	100	100	100
Vashington	2.72	2.20	3.00	7.87	7.11	7.31	2.78	7.31	2.33	2.10	2.00	1.34	1.10	1.10
'est Virginia	.94	.95	1.10	.82	æ.	08.	08.	.77	.75	89.	.65	.63	.61	.63
'yoming	3.00	3.00	3.00	1.26	1.70	1.53	1.27	1.35	1.31	1.33	c 1.37	1.21	1.28	1.24
Total hituminous	0106	01 10	0100	1 00	00	00	00	96	16	98	88	8	08	87
Pennsylvania anthracite	a 1.95	a 2.01	a 1.95	1.44	1.43	1.46	1.57	1.59	1.52	1.41	1.50	1.51	1.41	1.46
General average	a1.30	a 1.45	α 1.42	1.13	1.12	1.13	1.16	1.14	1.09	1.02	1.02	66:	.95	1.01

The cost for labor alone of coking coal has been given by a numb companies in the Connellsville district as 61 cents per ton of coke produ or 404 cents per ton of coal coked, exclusive of royalties, taxes, rents such fixed charges.

In the "American Manufacturer" for July 27, 1899, Mr. F. C. Keig gave the following as the proportional costs of the several items of mi

and coking Connellsville coal:

Coke Yard.	Per Cent.	Coke Yard.	C
Drawing Leveling Charging Carters Bookkeeper and superintendent, & of total for mine and yard Cleaning tracks	70.01 8.96 3.48 2.48	Shifting cars Yard bosses Masons on repairs Forking Individual cars Sundry Yard pumps Total	10

Mine.	Per Cent.	Mine.	Co
Room coal Drivers Heading coal Rope haulage Roads Mine bosses Fire boss Timber Trappers Superintendence, i of total for mine and yard Cagers Runners and oilers Engineers Firemen Dumpers	52.15 8.07 11.15 2.81 3.03 1.31 1.44 2.83 .43 .49 .66 .80 1.01 1.13 1.25	Machinist Bookkeeping, ‡ of total for mine and yard Outside labor Stable boss Teams Blacksmith Carpenters Lamp cleaners Inside pumps Steam pumps Surveys Extra men Supplies Betterments Total	1 100

The mine labor is 67.20% of the total labor cost, and the coke-yard lab

32.80% of the total labor cost.

The cost of equipping a coke plant and opening a mine to furnish coal in the Connellsville region is from \$500 to \$1,000 per oven, depender the kind of opening for the mine and local considerations. \$500 per ov a fair price for a plant when the conditions are favorable and the mine drift mine, and \$1,000 is a fair price for a shaft mine about 300 ft. d under rather unfavorable conditions.

Fulton gives the cost of the various types of coke ovens as follows:

Not saving by-products: Beehive, \$300; Thomas, \$800; McLanahan,
Belgian, \$1,000; Coppée, \$1,000; Bernard, \$1,000.

Saving by-products: Simon Carvès, \$1,300; Semet-Solvay, \$1,600; Hües
\$1,400; G. Seibel, \$1,300; Otto-Hoffman, \$1,600; Festner-Hoffman, \$1,500.

The usual quantity of coal required to make 1 ton of coke is 1.4 to 1.6 The loss in loading coke at the ovens and again unloading it at furnaces or steel works is 24 to 34. During the winter and in wet see coke takes on 24 to 34 of moisture in transit between the ovens and furnaces.

EXPLOSIVES.

The characteristics of a good blasting explosive are: (1) sufficient stability and strength; (2) difficulty of detonating by mechanical shock; (3) handy form; (4) absence of injurious effects on the user.

Explosives are divided into two general classes: (1) low explosives or direct-exploding materials; (2) high explosives or indirect-exploding mate-

rials that require a detonator.

Low Explosives.—Gunpowder or black powder is the type of this group. Its composition varies, depending on the purpose for which it is to be used, but the ingredients commonly used in its manufacture are saltpeter, sulphur, and charcoal.

The following table gives the composition of blasting powder in different

countries:

COMPOSITION OF BLASTING POWDER (Guttmann).

Ingredients.	Great Britain.	Germany.	Austria- Hungary.	France.	Russia.	Italy.	United States.
Saltpeter	75	66.0	64	62	66.6	70	64
Sulphur	10	12.5	16	20	16.7	18	16
Charcoal	15	21.5	20	18	16.7	12	20

High Explosives.—These are a mixture of nitroglycerine with an absorbing dope, the composition of which is such that, in addition to thoroughly and permanently absorbing the nitroglycerine, it is itself a gas-producing compound. Nitroglycerine at 60° F. has a specific gravity of 1.6. It is odorless, nearly or quite colorless, has a sweetish burny taste, is poisonous even very small quantities, and is insoluble in water. All nitroglycerine compounds freeze at 42° F., and explode when confined at 360° F. It takes fire at 306° F., and, if unconfined, burns harmlessly unless in large quantities, so that a part of it, before coming in contact with the air, becomes heated to

the exploding point.

Thawing Oynamita.—All frozen cartridges should be thawed, as, when frozen, cartridges are very hard to explode, and even if they do explode, the results are not nearly as satisfactory as when properly thawed. When cartridges are frozen, do not expose to a direct heat, but thaw by one of the following methods: First, place the number of cartridges needed for a day's work on shelves in a room heated by steam pipes (not live steam) or a stove. Where regular blasting is done, a small house can be built for this purpose, fitted with a small steam radiator. Exhaust steam through these pipes gives all heat necessary. Bank your house around with earth, or, preferably, fresh manure. Second, use two water-tight kettles, one smaller than the other, put cartridges to be thawed in smaller kettle, and place it in larger kettle, filling space between the kettles with hot water at, say, 130° to 140° F., or so that it can be borne by the hand. To keep water warm, do not try to heat it in the kettle, but add fresh warm water. Cover kettles to retain heat. In thawing do not allow the temperature to get above 212° F. Third, where the number of cartridges to be thawed is small, they may be placed about the person of the blaster until ready for use, the heat of the body thawing the cartridges. Keep cartridges away from all fires—this applies to all explosives. Do not be in a hurry, but thaw slowly. Do not thaw before an open fire. Do not put cartridges in an oven, on a hot stove, against hot iron plates, or against brick casing of a boiler. Do not put cartridges in hot water, or expose them to live steam. And do not take any kind of powder, fuse, or eaps near a blacksmith shop.

kind of powder, fuse, or caps near a blacksmith shop.

A large number of high explosives are made that vary but little in their composition, the main difference being in the character of the dope and in the percentage of nitroglycerine. The trade name is usually determined by the percentage of nitroglycerine, thus 10% dynamite means that the dyna-

mite contains 10% of nitroglycerine, etc.

Safety explosives, or, as they are called in England, permitted explosives, are compounds intended for use in gaseous mines, and they are so constituted

that they will ignite without producing the extremely high temperature given by ordinary explosives. The term flameless explosives was formerly used, but it has been replaced by safety explosives, as the absence of a flame is not now necessary to a permitted explosive.

COMMON BLASTING EXPLOSIVES.

At	las.		Br	ands Equi	ivalent in St	rength t	o Atlas.		
Brand. Per Cent. Nitroglycerine.		Repauno Gelatine. Hercules Powder.		Hercules Gelatine.	Giant Powder.	Giant Gelatine.	Hecla Powder.	Ætna Powder,	
A B+ C+ C+ D+ E+	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$		No. 1 XX No. 1 No. 2 SS No. 2 S No. 2	Old No. 1 No. 1 A New No. 1 No. 2 Extra No. 2 No. 2 C No. 3 XXX XXXX	No. 1 A No. 1 No. 2 No. 3 C	No. 1 XX No. 1 XS No. 1 X No. 1 X No. 2 X No. 2 No. 3 X No. 3	No. 1 No. 2 XX No. 2 X No. 2 X No. 3 No. 3 A No. 3 B No. 4		

Orilling.—Adapt the size and depth of the hole to the work to be accomplished. As a rule, for ordinary rock blasting, the distance between the holes should be equal to from one-half to the total depth of the holes, the holes set back from the face twice as far for dynamite as for common black powder, say a distance equal to the depths of the holes or slightly less, and load one-third the length of the hole. These directions are only general, and do not apply to very deep holes. Much depends on character and hardness of the rock, also on size of drill holes. In all cases, the experience and judgment of the blaster must be his guide.

Diameter of Holes.—In driving headings or sinking shafts, experience shows that holes having a diameter varying from ‡ to 1½ in. at the bottom are most economical in hard rock, if charged with the strongest high explosive. On the contrary, holes of large diameter, say 1½ to 2 in. in diameter, and charged with strong, low, and cheap explosive, are the best when operating in weak rock. All the holes in the heading or shaft should have the same diameter, and the best arrangement is to give an equal resistance of rock to each, and to so place each hole that it will receive the greatest benefit from

the free faces formed by firing the previous holes.

Relation of Diameter of Hole to Length of Charge.—By experiment, it has been proved that, as a rule, the length of the charge of explosive for single holes should not exceed from 8 to 12 times the diameter of the hole; that is, a 1" hole should never have a charge of more than 12 in. of explosive placed in it. Where several holes are fired together, this rule is sometimes slightly deviated from. It is usually best to employ a length of charge between these two limits, as, for instance, about 10 times the diameter of the hole.

Chambering or squibbing is the blasting out of a cavity at the bottom of a

drill hole to allow of a larger charge of explosive being used.

Bulling a drill hole is the working of clay into any cracks opening into a drill hole, to prevent the power of the blast being scattered through these cracks.

Charging.—The charge must fit and fill the bottom of bore and be packed solid. If holes are comparatively dry, slit the paper of the cartridges length wise with a knife, and as each is dropped into the hole, strike a wooden rammer on it with sufficient force to make the powder completely fill the bottom and diameter of the bore. Where water is not present, a more perfect loading is made by taking powder out of cartridge and dropping it in loosely, ram each 6 or 8 in. of the charge, using the paper of each cartridge as a wad, to take down any powder that may have stuck to the sides of the hole. If water is standing in the hole, do not break the paper of the cartridges and avoid ramming more than enough to settle the charge on the bottom using cartridges of as large diameter as will readily run into the bore.

bottom, using cartridges of as large diameter as will readily run into the bore.

When cartridges are used, the last cartridge placed in the hole should
contain an electric exploder, or cap with fuse attached. When loose powder is used, a piece of cartridge 2 or 3 in. in length, with exploder or cap attached, should be pressed firmly on top of charge. Some blasters put an exploder or cap in the first cartridge put in the hole, placing remainder of charge on top.

The charge should be placed in a solid part of the material to be broken. If

possible, the face should be undercut and then the overhanging material Best results are obtained when the bore holes cross the faces or shot down. layers of the material at right angles. The charges should be placed so as to disturb the sides and roof of a tunnel through material of medium hardness as little as possible. The charge at the bottom of the tunnel should be placed from 6 to 12 in. below the permanent level.

placed from 6 to 12 in. below the permanent level.

Amount of Charge.—No invariable rule can be laid down as to the diameter and length of cartridges to be used under any and all circumstances, nor the amount or grade of powder required for all kinds of work. Much depends on the good sense and judgment of the persons using the explosive. Guttmann, in his well-known handbook on blasting, says: "There is no lack of theories for the determination of blasting charges, but their application depends on empirical facts determined by practical work. I therefore advise that the calculation of charges under ordinary conditions be neglected, and recommend watching actual operations for some weeks, asking for explanation from the most expert miners. In this way experience will

iected, and recommend watching actual operations for some weeks, asking for explanation from the most expert miners. In this way experience will be gotten in a short time that will enable one to estimate with some precision the proper charge to use after inspecting the spot to be blasted."

A good rule by which to determine the weight of black powder to use in any given hole in bituminous workings is the following: Find the distance in feet from the charge out in the line of least resistance. Multiply the fourth power of this distance by the diameter of the hole in inches, and divide this product by the thickness of the seam in inches. The result will be the weight of the charge in pounds. Thus for a 2½ belg in a seam of be the weight of the charge in pounds. Thus, for a 21" hole in a seam of bituminous coal 6 ft. thick, where the charge is placed 4 ft. deep from the face of the coal, or cutting, we have for the weight of charge to be used,

$$\frac{9}{2} \times \frac{9}{2} \times \frac{9}{2} \times \frac{9}{2} \times \frac{.4 \times 2.5}{6 \times 12} = 5.7 \text{ lb.}$$

Tamping.—In deep holes, water makes a good tamping, but fine sand, clay, etc. are generally used. Fill in for the first 5 or 6 in. carefully, so as

clay, etc. are generally used. Fill in for the first 5 or 6 in carefully, so as not to displace cap and primer; then with a hardwood rammer pack balance of material as solid as possible, ramming with the hand alone, and not using any form of hammer. Never use a metal tamping rod.

Firing.—If the work is wet, or the charge used under water, use water-proof fuse, and protect the end of the fuse by applying bar soap, pitch, or tallow around the edge of the cap. Water must not be allowed to reach the powder in the fuse or the fulminate in the cap. Exploding by electricity is best under water at great depth, as the pressure of water is so great on the fuse that it is forced through and dampens it so as to prevent firing.

Seam Blusting.—If a seam is found in the rock, remove the powder from the cartriages and push it into the seam and fire a cap beside it. This will open the seam so that a larger quantity of explosive can be used, and the rock broken without drilling. In blasting coal, slate, marble, granite, freestone, or any other material that it is desirable to obtain in large blocks, cartridges of small diameter should be used in wide bore holes, the charge being rolled in several folds of paper, to prevent its touching the sides of the being rolled in several folds of paper, to prevent its touching the sides of the bore holes. The intensity of action and the crushing effect of the explosive are thus lessened.

Firing by Detonation.—Nitroglycerine explosives always require detonation by a cap or exploder in order to develop their full force. Fig. 1 illustrates the method of attaching such an exploder to the end of a fuse and the pla-cing of it in the cartridge. The exploders are loaded with fulminate or mercury and are slipped over the end of the fuse, after which the upper end is crimped tightly against the end of the fuse, as shown. (Miners somether bite the caps on to the fuse with their teeth. This is a very dangerous preceding and should never be allowed, as, with strong caps, one of the exploding in a man's mouth would prove fatal.) In placing the cap of

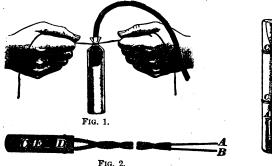




FIG. 3.

exploder into the dynamite or giant-powder cartridge, care should be taken that only about two-thirds of the cap be embedded in the material of the cartridge, for if the fuse had to pass through a portion of the material before reaching the cap, there would be danger of its igniting the material, thus causing deflagration of the cartridge in place of detonation. The tumes given off by high explosives are much worse in the case of detonating a cartridge.

The electric exploder, Fig. 2, has wires A and B, which carry the current to the exploder. D is a cement (usually sulphur) that protects the explosive compound C (usually mercury fulminate) and the whole is contained in a copper shell. A small platinum wire E is heated by the passage of a current

Fig. 4.

and ignites the explosive. Fig. 3 shows the method of placing a cap or an electric exploder in a cartridge of powder.

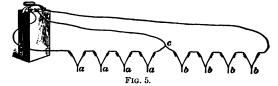
of powder.

When a number of holes are exploded at one time, the electric exploders are connected in series, as shown in Fig. 4, for a small number of holes, and as in Fig. 5 for a larger number.

The battery for furnishing the current of electricity is a magneto

machine that is worked by either pulling up or by depressing a handle or rack bar, or else by turning a crank.

Directions for Blasting by Electricity.—Drill the number of holes desired to be



fired at one time; depth and spacing of holes depending on character of rock, size of drill holes, etc., the blaster, of course, using his judgment in this matter. Load the hole in the usual manner, fitting one cartridge with a fuse

(electric exploder) instead of cap and fuse. The fuse head is fitted into the bottom end of the cartridge, or into the middle of one side of the cartridge, where a hole has been punched with a pencil or small sharp stick to receive it; push the powder close around the fuse head. The fuse can then be held in position by tying a string around the cartridge and the fuse wires binding the wires to the cartridge, as shown in Fig. 3. A shows head of fuse, B the two fuse wires, C string used to tie wires to cartridge. Avoid taking hitches in fuse wires, as by this very common practice, the insulation of the wires may be injured and the current of electricity may pass from one wire to the other, without passing through the cap, hazarding a misfire.

The cartridge containing the fuse is put in on top of the charge by some blasters; by others, at bottom of the charge. The best place for it is in the center of the charge, having part of the charge above and part below it. In tamping the hole great care must be taken not to cut the wires, or injure the cotton covering of fise wires, or to pull the fuse out of the cartridge. Allow

at least 8 in. of the fuse wires or to purt the ruse out of the catalogs. Another at least 8 in. of the fuse wire to project above the hole, to make connections. When all the holes to be fired at one time are tamped, separate the ends of the two wires in each hole, and, by the use of connecting wire, join one wire of the first hole with one of the second, the other or free wire of the second with one of the third, and so on to the last hole, leaving a free wire at each end hole.

All connections of wires should be made by twisting together the bare and clean ends; it is best to have the joined parts bright. Scrape off the cotton

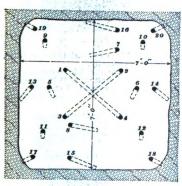


Fig. 6.



FIG. 7.

covering at the ends of the wires to be connected, say for 2 in., then rub the wire with a small hard stone. This makes a bright fresh wire. Be sure that all connections are clean, bright, and well twisted. Do not hook or loop wires in making connections. Bare joints in wire should never be allowed to touch the ground, particularly so if the ground is wet. This can be prevented by putting dry stones under the joints. The charges having all been connected, as directed above, the free wire of the first hole should be joined to one of the leading wires, and the free wire of the last hole to the other of the two leading wires. The leading wires should be long enough to reach a point at a safe distance from the blast, say 250 ft. at least. All being ready, and not till the men are at a safe distance connect the leading wires, one to each of the projecting screws on the front side or top of the battery, through each of which a hole is bored for the purpose, and bring the nuts down firmly on the wires. Now, to fire, take hold of the handle for the purpose, lift the rack bar (or square rod, toothed on one side) to its full length, and press it down, for the first inch of its stroke with moderate speed, but finishing the stroke with all force, bringing rack bar to the bottom of the box with a solid thud, and the blast will be made. Do not churn rack bar up and down. It

is unnecessary and harmful to the machine. One quick stroke of the rack bar is sufficient to make the blast. Never use fuses (exploders) made by different manufacturers in the same blast. Connecting wire should be of

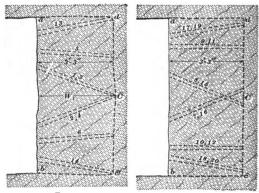
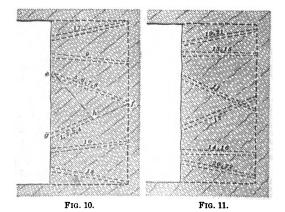


Fig. 8. FIG. 9.

same size as the fuse wire; leading wire should be at least twice as large. Covering on wire should not "strip" or come off easily.

The power of an explosive cannot be exactly calculated from the quantity and temperature of the gas resulting from its detonation, as it is impossible to determine the exact composition of gas at the moment of explosion and during the subsequent cooling period. Tables that give the relative strength

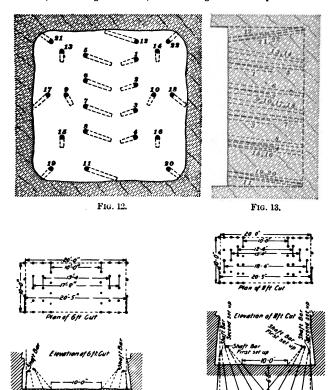


of explosives are apt to be misleading, as so much depends on the composition of the explosive, and since there are so many explosives of varying compositions that are sold under the same name.

Pressures Developed by Explosives.—According to experiments conducted

by Sarrau, Vielle, Noule, and Abel, the following approximate maximum pressures, in tons per square inch, developed by various explosives, have been arrived at: Mercury fulminate, 193; nitroglycerine, 86; guncotton, 71; blasting powder, 43.

Values of Explosives.—Taking gunpowder (containing 61% saltpeter) as a standard, and calling its value 1, the following are the comparative values



of the other explosives: Dynamite, containing 75% nitroglycerine, 2.2; blasting

FIG. 15.

gelatine, containing 924 nitroglycerine, 3.2; nitroglycerine, 3.3.

The strangement of drill holes for driving and sinking should be such as to permit the easy handling of the drills and also to minimize the number of holes and the weight of explosive. Two distinct systems are in use: (1) the center cut, by which a center core or key is first removed, and after that concentric layers about this core; (2) the square cut, in which the lines of holes are parallel to the sides of the excavation, the rock being removed

wedges instead of in concentric circles.

The center-cut method is shown in Figs. 6, 7, 8, and 9, Fig. 6 showing the face of a heading, Fig. 7 an elevation or vertical section, and Figs. 8 and plans. The numbers of the holes correspond in the several views. The less are supposed to be drilled by rock drills, and they are so placed the all except the breaking-in holes have an equal line of resistance. The number of the breaking-in holes have an equal line of resistance. ber of holes given is supposed to take out a clean cut of the whole section abcd to the extent of 3 ft. 6 in. The order of firing the holes is: (1) breaking-in shots 1, 2, 3, and 4 simultaneously; (2) 5, 6, 7, 8; (3) 9, 10, 11, 12; (4) 13, 14, 15, 16; (5) 17, 18, 19, 20.

(4) 15, 14, 15, 16; (3) 17, 18, 19, 20.

The square-cut arrangement is shown in Figs. 12 (face), 10, 11 (plans), and 13 (vertical elevation). The entering wedge, Fig. 11, is best removed in two stages: First, the part egh by the shots 1, 2, 3, and 4; and second, part efh by shots 5, 6, 7, and 8. The other shots are then fired: (1) 9, 10, 11, 12. (2) 13, 14, 15, 16; (3) 17, 18, 19, 20, each volley being fired either simultaneously or consecutively. Where there is a natural parting in the heading, advantage is, of course, taken of this in the location of the shots.

Figs. 14 and 15 show two arrangements of drill holes used in sinking the Parker shaft at Franklin Furnace, N. J. The size of the shaft was 10 ft. × 20 ft. in the rock. At first, only 6' cuts were put in, but these were gradually interested with 11 decreases. increased until 11' and 12' cuts were pulled. The best average obtained was 66 ft. of shaft from 6 consecutive cuts.

MACHINE MINING.

The number of coal-mining machines in use has increased rapidly within The number of coal-mining machines in use has increased rapidly within a very short time. In 1896 there were 1,446 in use in the United States. During 1897 there was an increase of 542, or 37.5%, while the average yearly gain from 1891 to 1896 was only about 22%. The total tonnage won by machines in 20 States in 1897 was 22,649,220 short tons, or 16.17% of the total product of these States, and 15.3% of the total bituminous product of the United States. A universal mining machine has not yet been brought out, and one of the principal reasons for the failure of mining machines in a number of instances has been the attempt to use a machine under conditions to which it was not adapted. When a mining machine is designed and built to suit the conditions under which it is to be operated, it is safe to say that there are but few mines in which they cannot be successfully utilized. They are of particular advantage where there is a long working face and where the coal is over 3 ft. in thickness. Low seams require more undercutting for the given output than high seams. As a rule it has not been found economical to use machines in seams pitching over 12° to 15°, though pick machines have been used in mines having an inclination of 23°, the difficulty being not so much in the cutting as in moving the machine from place to place.

There are four general types of mining machines in use; pick machines, chain-cutter machines, cutter-bar machines, and longwall machines. first two are the types almost universally used in America. Cutter-bar machines have almost entirely disappeared from use excepting one type which is at present used in Iowa. Longwall mining machines have not been very generally adopted in America, as the longwall method of mining

is not extensively used.

Both compressed air and electricity are used for operating mining machines. Pick machines driven by compressed air are made by three separate concerns. Four companies make electric chain machines and one of these four is also making a compressed air chain machine. One makes a longwall machine, and one has brought out a pick machine for electric power.

Pick machines work very similarly to a rock drill. They can be used wherever mining machines are applicable, and their particular advantage is that they are more perfectly under the control of the operator, who can cut around pyrites and similar obstructions without cutting them with the machine. This renders such a machine particularly applicable for seams of coal having rolls in the bottom and containing pyrites or other hard impuri-They are also applicable for working pillars on which there is a squeeze, as they are light and can be easily handled and readily removed.

Chain-cutter machines consist of a low metal bed frame upon which is mounted a motor that rotates a chain to which suitable cutting teeth are attached. To operate chain machines to the best advantage, the coal should attached. To operate chain machines to the best advantage, the coal should be comparatively free from pyrites. They also require more room than pick machines, and a space from 12 to 15 ft. in width is necessary along the face to work them to advantage. These machines have proved failures in some mines on account of the incessant jarring of the roof by the rear jack. Chain-cutter machines cannot be used to undercut coal when a squeeze is upon it. Coal seams that are comparatively level and free from pyrites and have a comparatively good roof can undoubtedly be more satisfactorily and economically cut with chain-cutter machines than with any other type.

The average height of cut is 41 to 5 in., and at this height, the chain-cutter machines makes only about 60% as much small coal as a pick machine. This is not always an advantage, as it does not always allow sufficient height for the coal to fall down after the cut is made. In a 31/ seam, 3 men are

required to handle the machine to advantage.

Shearing.—All the pick machines can be converted into shearing machines and can be used for longwall work by using a longer striking arm and a longer supply hose. The chain machines are used to do shearing work by

having the cutting parts turned vertically.

Capacity.—The average producing capacity of each mining machine used in the United States was 11,398 tons in 1891, 11,373 tons in 1896, and 11,393 tons in 1897. So much depends on the local conditions that it is almost impossible to give specific data of rates of working and costs, but the following are fair working approximations.

A good pick machine will undercut 450 sq. ft. in 10 hours, while an ordi-

nary miner will undercut 120 sq. ft. in the same time. In a seam varying from 41 to 6 ft. in thickness, the machine will undercut from 50 to 100 tons of coal in 10 hours. The cost of undercutting under these conditions has been given as approximately 10 cents per ton. Extraordinary records show 1,400 sq. ft. to have been cut in 9 hours in Western Pennsylvania, and in an 8' seam, 240 tons have been undercut in a shift of 10 hours.

A good chain cutter will make from 30 to 45 cuts, 44 in. wide and 6 ft. deep, in 10 hours under moderately fair conditions, while in high seams two men handling the same machine under ordinary conditions can make 60 cuts per shift, and under particularly favorable conditions, 80 to 120 cuts

per shift.

VENTILATION OF MINES.

This subject is divided naturally into (a) gases occurring in workings. explosive conditions, quantity of air, distribution of air, and (b) ventilating methods and machinery.

THE ATMOSPHERE.

Composition.—Air consists chiefly of oxygen and nitrogen, with small and varying amounts of carbonic-acid gas, ammonia gas, and aqueous vapor. These gases are not chemically combined, but exist in a free state in uniform proportion, as follows:

By	r Volume.	By Weight.
Nitrogen	79.3	77.0
Oxygen		23.0
•	100.0	100.0

Wherever air is found, its composition is practically the same.

Weight.—The weight of 1 cu. ft. of air at 32° F, and under a barometric pressure of 30 in. is .080975 lb. Air decreases in weight per cubic foot as we ascend in the atmosphere, and increases as we descend below the surface of the earth.

The weight of 1 cu. ft. of dry air at any temperature and barometer pressure is found by means of the formula

$$w=\frac{1.3253\times B}{459+t},$$

in which w= weight of 1 cu. ft. of dry air; B= barometric pressure (inches of mercury); t= temperature (degrees F.). The constant 1.3253 is the weight in pounds avoirdupois of 1 cu. ft. of drair at an absolute temperature of 1° F. and 1 in. barometric pressure. Example.—Find the weight of 1 cu. ft. of dry air at a temperature of 6° F. and a barometric pressure of 3° in.

$$w = \frac{1.3253 \times 30}{459 + 60} = .0766 \text{ lb.}$$

TABLE OF WEIGHT OF DRY AIR.

Weight of 1 cu. ft. of dry air at different temperatures and barometric pressures, as calculated by the formula $w = \frac{1.3253 \times B}{1}$

	405 T t						
Temperature. Degrees F.	Weight of 1 Cu. Ft. of Dry Air (Lb. Avoirdupois).						
	Barometer (In.). $B = 27$.	Barometer (In.). B = 28.	Barometer (In.). B = 29.	Barometer (In., $B = 30$.			
0	.07796	.08085	.08373	.08662			
5	.07718	.08002	.08285	.08569			
10	.07631	.07914	.08196	.08478			
15	.07550	.07830	.08109	.08388			
20	.07470	.07747	.08023	.08300			
25	.07393	.07667	.07941	.08215			
30	.07318	.07589	.07860	.08131			
32	.07288	.07558	.07828	.08098			
35	.07244	.07512	.07780	.08048			
40	.07171	.07435	.07701	.07967			
45	.07099	.07362	.07625	.07888			
50	.07031	.07291	.07551	.07811			
55	.06961	.07219	.07477	.07735			
60	.06895	.07150	.07405	.07660			
65	.06828	.07081	.07324	.07587			
70	.06766	.07016	.07266	.07516			
70 75	.06701	.06949	.07197	.07445			
80	.06648	.06884	.07130	.07376			
85	.06576	.06820	.07064	.07308			
90	.06519	.06760	.07001	.07242			
95	.06490	.06699	.06938	.07177			
100	.06401	.06638	.06875	.07112			
110	.06288	.06521	.06754	.06987			
120	.06180	.06409	.06638	.06867			
130	.06075	.06300	.06525	.06750			
140	.05974	.06195	.06416	.06637			
150	.05874	.06092	.06310	.06528			
160	.05781	.05995	.06209	.06423			
170	.05688	.05899	.06110	.06321			
180	.05601	.05808	.06015	.06222			
190	.05514	.05718	.05922	.06126			
200	.05430	.05631	.05832	.06033			
220	.05271	.05466	.05661	.05856			
240 240	.05271	.05309	.05498	.05688			
260	.04978	.05162	.05346	.05530			
280	.04840	.05020	.05200	.05380			
300	.04714	.03020	.05260	.05238			
350 350	.04423	.04587	.04751	.05238			
400	.04166	.04321	.04751	.04915			
300	.02100	.04021	.01470	.04029			

Atmospheric Pressure.—The term barometric pressure is the pressure caused by the weight of the atmosphere above a given point. It is measured by the barometer, and this gives rise to the synonymous term barometric pressure.

Atmospheric pressure is usually stated in pounds per square inch, while barometric pressure is stated in inches of mercury. Thus, at sea level, the atmospheric pressure under normal conditions of the atmosphere is 14.7 lb. per sq. in., while the barometric pressure at the same level is 30 in. of

mercury column, or simply 30 in.

Barometric Variations.—The pressure of the atmosphere is not constant, but is subject to fluctuations depending on the condition of the atmosphere. Besides these, there are fluctuations that are more or less regular and are called barometric variations. There is both a yearly and a diurnal, or daily variation. Of these two, the more important and the more regular is the daily variation, in which the barometer attains a maximum height from 9 to 10 O'clock A. M., and a minimum about 4 o'clock P. M. Other maximum and minimum readings are obtained at 10 P. M. and 3 A. M., respectively; but these are not as pronounced as those occurring in the daytime. The daily

barometric variations range from .01 to .08 in.

Mercurial Barometer.—This barometer is often called the cistern barometer; or, when the lower end of the tube is bent upwards instead of the mouth of or, when the lower end of the tube is been upwards instead of the mouth of the tube being submerged in a basin, it is known as the siphon barometer. The instrument is constructed by filling a glass tube 3 ft. long, and having a bore of \(\frac{1}{2}\) in. diameter, with mercury, which is boiled to drive off the air. The thumb is now placed tightly over the open end, the tube inverted, and its mouth submerged in a basin of mercury. When the thumb is withdrawn, the mercury sinks in the tube, flowing out into the basin, until the top of the mercury column is about 30 in. above the surface of the mercury in the basin, and after a few oscillations above and below this point, comes to rest. basin, and after a few oscillations above and below ins point, comes to rest. The vacuum thus left in the tube above the mercury column is as perfect a vacuum as it is possible to form, and is called a Torricelli vacuum, after its discoverer. There being evidently no pressure in the tube above the mercury column, and as the weight of this column standing above the surface of the mercury in the basin is supported by the pressure of the atmosphere, it is the exact measure of the pressure of the atmosphere on the surface of the mercury will be found to average about 30 in at level the beight of the mercury will be found to average about 30 in at level, the height of the mercury will be found to average about 30 in, at higher elevations it is less, while if we descend deep shafts below this level, it is greater. Roughly speaking, an allowance of 1 in. of barometric height is made for each 900 ft. of ascent or descent from sea level (see calculation of barometric elevations). A thermometer is attached to each mercurial barometer to note the temperature of the reading, as it is customary in all accurate work with this instrument to reduce each reading to an equivalent reading at 32° F., which is the standard temperature for barometric readings. A scale is provided at the top of the mercury column with its inches so marked upon it as to make due allowance for what is called the error of capacity. In other words, the inches of the scale are longer than real inches, since the level of the mercury in the basin rises as it sinks in the tube, and vice versa. The top of the mercury column is always oval, convex upwards owing to capillary attraction, and the scale is read where it is tangent to this convex surface.

Aneroid Beremeter.—This is a more portable form than the mercurial barometer. It consists of a brass box resembling a steam-pressure gauge, having a similar dial and pointer, the dial, however, being graduated to read inches, corresponding to inches of mercury column, instead of reading pounds, as in a pressure gauge. Within the outer case is a delicate brass box having its upper and lower sides corrugated, which causes it to act as a bellows, moving in and out as the atmospheric pressure on it changes. The air within the box has been partially exhausted, to render it sensitive to atmospheric changes. The movement of the upper surface of the box is communicated to the pointer by a series of levers, and the dial is graduated

to correspond with the mercurial barometer.

Calculation of Atmospheric Pressure.—The weight of the mercury column of the barometer is the exact measure of the pressure of the atmosphere, since it is the downward pressure of the atmosphere that supports the mercury column, area for area; that is to say, the pressure of the atmosphere on 1 sq. in. supports a column of mercury whose area is 1 sq. in., and whose height is such that the weight of the mercury column is equal to the weight of the atmospheric column. Hence, since 1 cu. in. of mercury weighs .49 lb., the atmospheric pressure that supports 30 in. of mercury column is .49 × 3 = 14.7 lb. per sq. in. In like manner, the atmospheric pressure corresponding to any height of mercury column may be calculated. It will be observed that the sectional size of the mercury column is not important, since it supported by the atmospheric pressure on an equal area, but the calculation of pressure is based on 1 sq. in.

of pressure is based on 1 sq. in.

Water Column Corresponding to Any Mercury Column.—The density of mercur referred to water is practically 13.6; hence, the height of a water column corresponding to a given mercury column is 13.6 times the height of the mercury column. For example, at sea level, where the average barrometr pressure is 30 in. of mercury, the height of water column that the atmospheric pressure will support is $13.6 \times \frac{3}{18} = 34$ ft. This is the theoretical height to which it is possible to raise water by means of a suction pump, but the length of the suction pipe should not exceed 75% or 80% of the theoretical vector column. water column.

Calculation of Barometric Elevations.—Such elevations, although approximate, are useful for many purposes. The barometric readings are reduced to equivalent readings at the standard temperature of 32° F., and for determining differences in elevation, the readings of two barometers should be taken, if possible, at the same time. It must not be supposed, however, that the barometer always reads the same for the same elevation at this temperature. The temperature of the atmosphere has indeed very little effect on the atmospheric pressure, which is due to the weight of air above the point of observation, aerial currents, and other phenomena.

In the more accurate determinations of vertical height or elevation by

means of the barometer, the following formula is usually employed:

R =reading of barometer (inches) at lower station; $\underline{r} =$ reading of barometer (inches) at higher station;

T = temperature (F.) at lower station; t = temperature (F.) at higher station; H = difference of level in feet between the two stations.

$$H = 56,300 (\log R - \log r) \left(1 + \frac{T+t}{900} \right).$$

$$\therefore \log R = \frac{H}{56,300 \left(1 + \frac{T+t}{900} \right)} + \log r.$$

$$\begin{array}{ll} \text{More simply:} & H = 49,000 \Big(\frac{R-r}{R+r} \Big) \Big(1 + \frac{T+t}{900} \Big). \\ & \therefore & R = r \left[\frac{49,000 \left(900 + T + t \right) + 900 \, H}{49,000 \left(900 + T + t \right) - 900 \, H} \right]. \end{array}$$

Correction for Temperature.—Mercury expands about .0001 of its volume for each degree Fahrenheit. To reduce, therefore, a reading at any temperature to the corresponding reading at the standard temperature of 32° F., subtract \(\tau_1\text{totalog}\) of the observed height for each degree above 32°; or, if the temperature is below 32°, add \(\tau_1\text{totalog}\) for each degree.

Thus, 30.667 in. at 62° F. is equivalent to a reading of 30.555 in. at 32° F.,

since
$$30.667 - \frac{62 - 32}{10.000} (30.667) = 30.667 - .092 = 30.555 in.$$

Depth of Shafts.—The barometer is often employed to determine the depth of a shaft or the depth of any point in a mine below a corresponding point on the surface. The aneroid is employed for this work, being more portable. Allowance must always be made in such cases for the venti-lating pressure of the mine. A simple formula often used for such calculations is the following:

$$H = 55,000 \left(1 - \sqrt{\frac{r}{R}}\right),$$

in which the letters stand for the same factors as designated above.

The most important use of the barometer in mining practice, however is found in the warning that it gives of the decrease of atmospheric pressure, and the expansion of mine gases that always follows.

CHEMISTRY OF GASES.

All matter exists in one of three forms, solid, liquid, or gaseous, according to the predominance of the attractive or the repulsive forces existing between the molecules. For example, water exists as ice, or in a solid form, when the attractive force exceeds the repulsive force between its molecules. As the temperature is raised or heat is applied, the ice assumes the liquid form due to the more rapid vibration of the molecules of which it is composed. In other words, the repulsive force existing between the molecules is increased, and the result is a liquid. If we still further raise the temperature by applying more heat, the vibration of the molecules becomes yet more rapid, the repulsive force is increased between the molecules, and a gas or vapor called steam is formed.

An atom is the smallest conceivable division of matter.

A molecule is a collection of two or more atoms, united by affinity.

The atom cannot consist of more than one element. The molecule may be either simple or compound. If compound, it is a chemical compound, its atoms being chemically united.

Chemical Compounds.—A chemical compound is one formed by the union of two or more atoms chemically, such atoms uniting always in fixed or definite proportions. The properties of a chemical compound are always the same.

Sechanical Mixture.—A mechanical mixture is composed of different substances that are not chemically united, and which are mixed in no fixed proportion. The properties of a mechanical mixture present a regular gradation from a maximum to a minimum state. Thus, a solution of gradation from a maximum to a minimum state. Thus, a solution of common salt NaCl in water is not a chemical compound of salt and water, but simply a mechanical mixture of the salt in the water. If more salt is added to the water, the strength of the mixture or the brine is increased; and when less salt is present, the strength is less. On the other hand, salt itself is a chemical compound formed by the union of 1 atom of sodium with 1 atom of chlorine, the two atoms being bound together by chemical affinity, and always uniting in the same proportion, 1 atom of each. to form salt.

The air that we breathe is a mechanical mixture of nitrogen and oxygen gases, with small amounts of other ingredients. The nitrogen and oxygen gases are in a free state; that is to say, they are not combined as in a chemical compound. This is true, although the proportion of these two gases, oxygen and nitrogen, in the atmosphere, is uniformly in the ratio of, say, 1 volume of oxygen to 4 of nitrogen. Firedamp is another example of true mechanical mixture, consisting chiefly of a mixture of marsh gas CH₄ and air, with small amounts of other hydrocarbons and a varying amount of carbonic-acid gas, which is always present in firedamp. These gases are not

combined chemically, but are mixed in varying proportions.

Atomic volume, or specific volume, means simply relative volume. terms refer to the relative volume of gases resulting from any particular reaction. By means of the laws of atomic volume, we can ascertain the volumes of the different gases resulting from any particular reaction. The chemical reaction that takes place between the elements constituting the different gases is expressed by means of a chemical equation. When we have expressed such reaction by a chemical equation, we can then calculate the volumes of the gases formed, with respect to the original volumes of the gases entering into the reaction. It must be observed, however, that the atomic volumes express merely the relative volumes of gases; or, in other words, the ratio of the volumes of gases before and after the reaction takes place.

Laws of Volume.—The following laws of volume refer to gases only, and

never to solids or liquids:

First.—Equal volumes of all gases, under the same conditions of temperature and pressure, contain the same number of molecules. Hence, the molecules of all simple gases are of the same size.

Second .- The molecules of compound gases, under like conditions of temperature and pressure, occupy twice the volume of an atom of hydrogen gas. There are very few exceptions to these two laws of gaseous volume, and the exceptions are unimportant so far as mining practice is concerned.

An element is a form of matter that is composed wholly of like atoms.

Thus, hydrogen, oxygen, iron, copper, gold, and silver are elements.

Chemical Symbols and Equations.—To facilitate the writing of chemical

equations expressing the reaction that takes place between elements unde certain conditions, it is usual to express the elements by letters calle symbols. These symbols stand for the elements that they represent, and as written as capital letters, except where two letters are used to express symbol, in which case the first letter only is a capital. Thus, C is the symbol for the element carbon, but Cu is the symbol for copper (cuprum and Co is the symbol for cobalt. It is important that these symbols be written exactly in this manner; otherwise they are liable to be frequently misconstrued. For example, Co stands for cobalt, while the symbol of

TABLE OF ELEMENTS.

Element.		Atomic Weight.	Element.	Symbol.	Atomic
Aluminum	Al	27.5	Manganese	Mn	55.0
Antimony (stibium)	Sb	120.0	Molybdenum	Mo	96.
Argon(?)	A		Neodymium(?)	Nd	
Arsenic	As	75.0	Nickel	Ni	58.
Barium	Ba	137.0	Niobium	Nb	94.
Beryllium	Be	9.4	Nitrogen	N	14.
Bismuth	Bi	208.0	Osmium	08	191.0
Boron	B	11.0	Oxygen	0	16.
Bromine	Br	80.0	Palladium	Pd	106.
Cadmium Cæsium	Cd	112.0	Phosphorus	P	31.
Calcium	C8	133.0	Platinum	Pt	197.
	Ca	40.0	Pottasium (kalium)	K	39.
Carbon	C	12.0	Praseodymium(?)	Pr	3011
Chlorine	Ce	138.0	Rhodium	Rh	104.
Chromium	Cl	35.5	Rubidium	Rb	85.
	Cr	52.5	Ruthenium	Ru	104.
Cobalt	Co	59.0 93.7	Samarium(?)	Sa Sc	
	Cb	63.0	Scandium		PO (
Copper (cuprum)	D	147.0	Selenium	Se Si	79.0
Didymium	Er	169.0	Silver (argentum)		28.0
Erbium(?)	F	19.0	Silver (argentum)	Ag Na	108.0
Fluorine	Ga	69.0	Sodium (natrium) Strontium	Sr	23.0 87.5
	Ge	09.0	Sulphur	S	32.0
Germanium	Au	196.7	Tantalum	Ta	182.0
Gold (aurum)	He	130.7	Tellurium	Te	127.0
Helium(?)	H	1.0	Thallium	Ti	205.0
Hydrogen	In	113.4	Thorium	Th	231.5
odine	I	127.0	Tin (stannum)	Sn	108.0
ridium	Ir	193.0	Titanium	Ti	48.0
fron (ferrum)	Fe	56.0	Tungsten (wolfram)	W	184.0
Lanthanum	La	139.0	Uranium	U	240.0
Lead (plumbum)	Pb	207.0	Vanadium	V	51.2
Lithium	Li	7.0	Ytterbium	Yb	02.2
Magnesium	Mg	24.0	Yttrium	Y	89.0
Mercury (hydrargy-	3		Zine	Zn	65.0
rum)	Hq	200.0	Zirconium	Zr	90.0

stands for carbonic-oxide gas, which is a chemical compound composed of two elements, carbon and oxygen.

A molecule is expressed by writing the symbols of its elementary atoms. Where more than 1 atom of a substance or element enters into the composition of a molecule, the number of atoms of such element is expressed by small subscript letter written immediately after the symbol of the element. Thus, carbonic-acid gas is composed of 1 atom of carbon chemically united with 2 atoms of oxygen, and is expressed by the symbol CO₂. Where the symbol is written without such subscript figure, 1 atom only is meant. Thus, carbonic-oxide gas being composed of 1 atom of carbon chemically

ted to 1 atom of oxygen, is expressed by the symbol CO.

large figure written before the symbols expressing the molecule indist the number of molecules entering into the reaction. A large figure is etimes used before the symbol of a single element to indicate the number come of that element that enter the reaction. In any reaction occurring veen atoms of matter, no matter is destroyed. In any reaction, there always the same number of atoms after the reaction as before the tion took place. A chemical equation is therefore an expression of ality between the atoms before and after a reaction takes place. The member of the equation contains the substances that act upon each er, while the second member of the equation contains the substances are formed by the reaction. The number of atoms is the same in each mober of the equation. large figure written before the symbols expressing the molecule indi-

The formed by the reaction. The number of the equation. Example.—To express the reaction that takes place when carbonic-de gas burns in the air to produce carbonic-acid gas, we write $CO + O + 4N = CO_2 + 4N$ In this equation, each molecule of carbonic-oxide gas CO takes up 1 atom

he free oxygen of the atmosphere to form carbonic-acid gas CO_2 . The rogen in the atmosphere being 4 times the volume of oxygen, is expressed a atoms in the equation. This nitrogen, however, remains inactive, and less no part in the reaction. It is written on both sides of the equation for purpose of determining the atomic volumes of the gases before and after reaction, as explained below.

The reaction for an explosion of firedamp is $CH_4 + 4O + 16N = CO_2 + 2H_2O + 16N$

In this equation, each molecule of marsh gas CH_i is dissociated; that is say, its atoms are separated. The atom of carbon in the molecule unites the 2 atoms of the oxygen of the air to form carbonic-acid gas CO_2 . The toms of hydrogen, in like manner, combine with two atoms of oxygen in toms of hydrogen, in like manner, combine with two atoms of oxygen in eair to form 2 molecules of water or steam 2(H₂O), or 2H₂O. The nitron in this equation is equal to 4 times the volume of the oxygen consumed, d is therefore written as 16N, since a total of 4 atoms of oxygen have en used. The nitrogen is however inert, and plays no part in the reaction itself, but is written here on both sides of the equation, as in the example of the equation, in order to properly represent the atomic volumes of egases or their relative volumes before and after the reaction takes place. Calculation of the Relative Volumes of Gases.—To calculate the relative lumes of the gases before and after the reactions expressed in each of the uations given in the preceding paragraphs, write beneath the symbol each molecule or atom its atomic volume. In the chemical equation pressing the reaction that takes place when carbonic-oxide gas CO burns

pressing the reaction that takes place when carbonic-oxide gas CO burns carbonic-acid gas CO2, we have as follows:

 $CO + O + 4N = CO_2 + 4N$

Atomic volumes, 2+1+4=2+4, in this reaction, 7 volumes have been reduced to 6 volumes. Such a ange of volume often takes place in chemical reactions. All attempts to plain the cause of this change of volume, however, have thus far failed; it that the change of volume does take place has been demonstrated by a

To calculate the volume of air consumed in the complete explosion of 0 cu. ft. of carbonic-oxide gas CO, we write the ratio of the relative volumes carbonic-oxide gas and air, which is 2:(1+4), or 2:5; and to obtain the tual volume of air consumed in the explosion of 100 cu. ft. of carbonic-

 5×100 cide gas, we write the proportion 2:5::100:x, or x=

To find the volume of carbonic-acid gas CO₂ produced in the complete plosion of 100 cu. ft. of carbonic-oxide gas CO, write the ratio of the atomic plumes of these two gases 2: 2, which shows no change of volume, and, erefore, the volume of carbonic-acid gas CO₂ produced will be the same as e volume of carbonic-oxide gas CO burned.

To find the volume of air consumed in the complete explosion of 100 1. ft. of marsh gas CH_1 , write the equation expressing the reaction that kes place in this explosion as given above,

 $\begin{array}{c} CH_4+4O+16N=CO_2+2H_2O+16N\\ \text{Atomic volumes, }2+4+16=2+4+16\\ \text{There is no change of volume caused by the explosion, since 22 volumes} \end{array}$ n one side of the equation produce, likewise, 22 volumes on the other side; 22 volumes before the explosion produce 22 volumes after the explosion. To find the volume of air consumed, we write the ratio of the atomic volumes of marsh gas and air 2:(4+16), or 2:20, or 1:10; that is to say, roughly speaking, the amount of air consumed in the complete explosion of the same of the complete explosions. sion of marsh gas is 10 times the volume of the marsh gas. This is not exact, however, as the volume of nitrogen in the air is 3.83 times the volume of oxygen. Making this correction, the volume of air consumed in the complete explosion of marsh gas is 9.66 times the volume of the gas.

To determine the preparate of ways marsh and the latest and the complete explosion of marsh gas is 9.66 times the volume of the gas.

To determine the percentage of pure marsh gas in the above firedamp mixture (marsh gas and air), we write the ratio of the atomic volumes of

these two, 2: (2+4+15.32), or 1: 10.66; and $\frac{1}{10.66} \times 100 = 9.38\%$ of CH_4 .

The volume of carbonic-acid gas formed in this reaction is equal to the volume of marsh gas consumed, and the volume of watery vapor is double the volume of marsh gas consumed; the total volume of gas and vapor formed by the reaction is the same as the original volume of marsh gas and air, or firedamp mixture, since the sum of the atomic volumes on each side of the equation is the same.

Atomic weight is the relative weight of an atom of an element compared with an atom of hydrogen. Atomic weight is, then, not an absolute weight to be expressed in pounds, ounces, or any other denomination, but is simply relative weight. The atomic weight of each of the elements is given in the

table on page 342.

Molecular weight is the sum of the atomic weights of the elements forming the molecule, taking the atomic weight of each element as many times as there are atoms of that element in the molecule. A molecule of water is composed of 2 atoms of hydrogen and 1 atom of oxygen, and as the atomic weight of hydrogen is 1 and that of oxygen 16, the molecular weight of water is $(2 \times 1) + 16 = 18$. In the same manner, since a molecule of marsh gas CH_4 is composed of 4 atoms of hydrogen and 1 of carbon, and the atomic weight of hydrogen is 1 and that of carbon 12, the molecular weight of marsh gas is $(4 \times 1) + 12 = 16$.

The density of a gas is the weight of any volume compared with the weight of the same volume of hydrogen or some other standard. density of a gas is constant at all temperatures and pressures, the change of temperature and pressure affecting the gas in question and the standard alike. The density of air referred to hydrogen is 14.38.

(a) The density of any simple gas, referred to hydrogen as unity, is equal to its atomic weight. (b) The density of any compound gas, referred to hydrogen as unity, is one-half of its molecular weight.

Specific Gravity of Gasas.—The specific gravity of a gas is the weight of that gas referred to the weight of a like volume of air as a standard. It is, in other words, the ratio between the weight of like volumes of any gas and air, both the air and gas being subject to the same temperature and pressure. Thus, since the weight of 1 cu. ft. of air at a temperature of 60° F. and 30 in. barometric pressure is .0766 lb., and the weight of 1 cu. ft. of carbonic-acid gas CO₂ is .11712 lb. at the same temperature and pressure, the specific

gravity of carbonic-acid gas is .11712 = 1.529.

Weight of Gases.-The weight of 1 cu. ft. of any gas at any given temperature and pressure is found by first calculating the weight of 1 cu. ft. of dry air at the same temperature and pressure by means of the formula given on page 338 for air, and then multiplying this weight by the specific gravity of the gas referred to air as a standard.

EXAMPLE.—To determine the weight of 1 cu. ft. of carbonic-acid gas at a temperature of 60° F., and 30 in. barometric pressure, we multiply the weight of 1 cu. ft. of dry air, at this temperature and pressure, as found above (.0766 lb.), by the specific gravity of carbonic-acid gas (1.529). Thus

 $.0766 \times 1.529 = .11712 \text{ lb.}$

The table on page 349 gives the specific gravity of the gases common in

mining practice, referred to air as a standard.

Expansion of Air and Gases.—All air and gases expand uniformly at the same rate. The expansion and contraction of air and gases follow two simple laws that we will consider under the heads (a) Ratio of volume and absolute temperature and (b) Ratio of volume and absolute pressure.

Absolute temperature means the temperature as reckoned from absolute zero, which is the point on the temperature scale below which it is assumed that no substance can exist in a gaseous state. The absolute zero of the

Fahrenheit scale is assumed in mining practice as 459° below zero. Hence, the absolute temperature corresponding to any common temperature is found by adding 459° to the common temperature. Thus, the absolute

temperature corresponding to 60° F. is $459 + 60 = 519^{\circ}$.

Absolute Pressure.—The term absolute pressure refers to the total pressure supported by air or gas; i. e., the pressure above a vacuum. Gauge pressure is the pressure above the atmosphere. Absolute pressure is always the atmospheric pressure plus the gauge pressure. If a gauge pressure about the atmospheric pressure of the property of the absolute pressure supported by the steam in the boiler will be 60 + 14.7 = 74.7 lb. per sq. in. Or, if the ventilating pressure in a mine is equal to 13 lb. per sq. ft., the absolute pressure supported by the air in the airways will be $13 + (14.7 \times 144) = 2,129.8$ lb. per sq. ft.

Relation of Volume and Absolute Temperature (Charles' or Gay Lussac's law).
The volume of any air or gas varies directly as its absolute temperature.
Relation of Volume and Absolute Pressure (Boyle's or Mariotte's law).—The
volume of any air or gas varies inversely as the absolute pressure it supports.
For example, if we double the absolute pressure supported by air or gas, the volume of the air or gas will be reduced to one-half its original volume; if we multiply the absolute pressure 3 times, we reduce the volume to onethird the original volume; etc.

EXAMPLE.—The intake current of a mine is 50,000 cu. ft. of air per minute; the ventilating pressure is 13 lb. per sq. ft. The temperature of the intake is 20° F.; the temperature of the return air is 70° F. Calculate the volume of the return air-current per minute, according to the rules of expansion of air, due to the increase of temperature and decrease of pressure, in the return

current.

The increased volume of the return air, due to the decrease of pressure and increase of temperature, is found by writing a compound proportion, the first member of which consists of two ratios, viz., the direct ratio of the absolute temperatures, and the inverse ratio of the absolute pressures, according to the two laws stated above. That is, we write

$$(459 + 20) : (459 + 70) 2,116.8 : 2,129.8 Or,
$$z = \frac{529 \times 2,129.8 \times 50,000}{479 \times 2,116.8} = 55,558 \text{ cu. ft.}$$$$

EXAMPLE.—In a compressed-air plant, the gauge shows a pressure of 80 lb. per sq. in.; the area of the piston is 20 sq. in., and its stroke 10 in. makes 100 strokes per minute. Assuming there is no leakage of air past the piston, what will be the volume of air discharged from the pump into the mine per minute?

The volume of air discharged from the pump cylinder per minute $20 \times 10 \times 100$ = 11.57 cu. ft. (cylinder pressure). The absolute pressure

on the air in the cylinder is 80 + 14.7 = 94.7 lb. The absolute pressure on the discharged air is simply the atmospheric pressure (14.7 lb.). Hence, we

write the proportion 14.7: 94.7:: 11.57: x; or, $x = \frac{94.7}{14.7} \times 11.57 = 74.54$ cu. ft.

per minute, nearly.

In calculating the expanded volume of air or gas, it will be observed that the ratio of the original volume to the expanded volume is always equal to the product of the direct ratio of the absolute temperatures and the inverse ratio of the absolute pressures, which gives a compound proportion, the first member of which consists of two ratios, the one a direct ratio and the other an inverse ratio.

Weight Produces Pressure.—In the study of the barometer as a means of measuring atmospheric pressure, we observe that the weight of the atmosphere produced the atmospheric pressure. In like manner, the weight of all fluids produces pressure, and this pressure acts equally in all directions. This is an important consideration in the study of mine ventilation, since it has given rise to the measurement of pressure by air or motive columns.

Calculation of Pressure.—An air column, or motive column, in ventillation, is a column of air having a base of 1 sq. ft., and of such height that its weight shall be equal to any given pressure. To calculate the height of air column corresponding to any given pressure, divide the pressure in pounds per square foot by the weight of 1 cu. ft. of the air. Mine pressure is also measured by the water column that it will support, as in the water gauge, or the mercury column, as in the barometer. In the measurement of pressu by means of the water column, the weight of the water column must

equal to the pressure, area for area. Since the weights of these columns are proportional to their sectional are

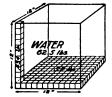


Fig. 1.

it makes no difference what this area may be, the weight of the colum calculated for a sectional area of 1 sq. in. w equal the pressure per square inch that support

the same.

Hence, since 1 cu. in. of mercury weighs .49 lb A9 × 30 = 14.7 lb. is the atmospheric pressur-corresponding to a height of 30 in. of mercury, of as we say, 30 in. of barometer. If we consider cubical box, as shown in the accompanyin figure, holding exactly 1 cu. ft. of water, an assume the weight of the water to be 62.5 lb., as is usual in practice, and divide the bottom of the box into 144 sq. in., as shown in Fig. 1, we observe:

The pressure of the water on the bottom (a) of the box is equal to the weight of the water, 62.5 lb.; that is to say, the pressure per square foot due to 1 ft. of water column

is 62.5 lb (b) The pressure on the bottom of the box, when the water is only 1 in. deep, is equal to the weight of a layer of water 1 in. thick, or

= 5.2 lb.; or, the pressure per square foot due to 1 in. of water column is 5.2 lb.

(c)

The pressure per square inch on the bottom of the box is equal to the weight of a prism of water 1 ft. high, and having a base of 1 sq. in. = .434; or, the pressure per square inch due to 1 ft. of water column is .434 b.

These principles relating to the pressure of fluids are important to the

student of mining, of which the following are examples:

In a mountainous country, several thousand feet above sea level, where the barometer registers, say, only 21 in., it is desired to know the theoretical height a pump will draw. $.49 \times 21 = 10.29$ lb. atmospheric pressure, and $\frac{10.29}{}$ = 24 ft., nearly. The theoretical suction, in this instance.

is 24 ft., nearly, but the actual draft or suction would vary from \ to \ of this, according to the perfection of the pump. The water-gauge reading between the intake and return airways of a

certain mine is 2.5 in.; to determine the pressure per square foot, we have, $2.5 \times 5.2 = 13$ lb. per sq. ft. 3. To determine the pressure per square foot on a mine dam, due to a vertical head of 200 ft., $62.5 \times 200 = 12,500$ lb.

To express in air column or motive column, a mine pressure equivalent to a water-gauge reading of 3 in., assuming the temperature of the air to be 60° F. and the barometric pressure 30 in., we have for the weight of 1 cu. ft. 1.3253×30

of air at this temperature and pressure w == .0766 lb.The 459 + 60pressure per square foot due to 3 in, of water gauge is $3 \times 5.2 = 15.6$. we have for motive column, $m = \frac{20.5}{.0766}$ = 204 ft.

Diffusion and Transpiration of Gases. - Diffusion of gases means the mixing of the gaseous volumes. Graham took several glass tubes, and inserting in one end of each a plug of plaster of Paris that was porous, he filled each tube with a different gas; as for example, oxygen, hydrogen, nitrogen, etc. He then placed the open end of each inverted tube in a basin of mercury, supporting the tubes in an erect position. The gas in each tube immediately began to diffuse through the porous plaster plug into the atmosphere, and it was observed that the mercury rose in each tube to take the place of the gas that passed into the atmosphere. The mercury rose in the hydrogen tube 4 times as fast as in the oxygen tube, and in the other tubes the mercury rose at different rates.

Rate of Diffusion (Graham's Law).—The rate of diffusion of gases into air is

e inverse ratio of the square roots of their densities. The density of en being 16 and hydrogen 1, the rate of diffusion of oxygen as compared hydrogen is 1 to 4; that is to say, the rate of diffusion of oxygen is only ourth that of hydrogen.

E SHOWING THE CORRESPONDING MERCURY AND AIR COLUMNS, AND PRESSURE PER SQUARE FOOT FOR EACH INCH OF WATER COLUMN.

	i		1	!	· ·	
Mercury Column	Air Column.	Pressure.	Water Gauge.	Mercury Column.	Air Column.	Pressure.
Inches.	Feet (T. 60°, B. 30"	Lb. per Sq. Ft.	Inches.	Inches.	Feet (T. 60°, B. 30″	Lb. per Sq. Ft.
.0735	68	5.2	6	.4412	407	31.2
.1471	136	10.4	7	.5147	475	36.4
.2206	204	15.6	8	.5882	543	41.6
.2941	272	20.8	9	.6618	611	46.8
.3676	340	26.0	10	.7353	679	52.0
	.0735 .1471 .2206 .2941		Mercu Air Feet (T	Mercu Air Feet (T Lb. I	Mercu Mercu Mercu	Mercu Reet (T Lb. I Lb. I Mercu Mercu Air

3LE SHOWING THE CORRESPONDING WATER COLUMN, AND PRESSURE PER SQUARE FOOT FOR EACH INCH OF MERCURY COLUMN.

arometer. Inches.	Water Column. Feet.	Pressure. Lb. per Sq. In.	Barometer. Inches.	Water Column. Feet.	Pressure. Lb. per Sq. In
1 2 3 4 5 6 7 8	1.13 2.27 3.40 4.54 5.67	.49 .98 1.47 1.96 2.45	16 17 18 19 20	18.13 19.27 20.40 21.53 22.67	7.84 8.33 8.82 9.31 9.80
6 7 8 9 10 11 12 13 14	6.80 7.93 9.06 10.20 11.33 12.46 13.60 14.73 15.87 17.00	2.94 3.43 3.92 4.41 4.90 5.39 5.88 6.37 6.86 7.35	21 22 23 24 25 26 27 28 29	23.80 24.93 26.07 27.20 28.33 29.47 30.60 31.73 32.87 34.00	10.29 10.78 11.27 11.76 12.25 12.74 13.23 13.72 14.21

Note.—One foot of water column is equivalent to a pressure of .434 lb. per in. The weight of air at 60° F., barometer 30 in., is $_{1.5}$ the weight of ter; but the ratio of air to water is often assumed as 1.2° 1,000, for quick culation. The specific gravity of mercury at 32° F. (standard temperate for barometric readings) is 1.62; and a cubic foot of mercury at this aperature weighs 849 lb. For ordinary calculation, the weight of 1 cu. ft. water is taken as 62.5 lb. The exact weight of 1 cu. ft. of pure water, at a aperature of 32° F., is, however, 62.418 lb.

The diffusion of marsh gas (Sp. Gr. .559) is much more rapid than that of rbonic-acid gas (Sp. Gr. 1.529). The diffusion of gases, however, is greatly sisted by the movement of the air-current; or by the movement of the gas it tends to rise or fall, according to its relative density and position in the way. For example, suppose a gas feeder to be located in the floor of an way. The marsh gas given off from the feeder, being lighter than air.

tends to rise toward the roof. The action of rising helps a diffusion of the gas very much. On the other hand, a feeder located in the roof gives off the same gas, which tends to accumulate along the roof, and if the air-curre is at all sluggish at this point, the diffusion of the marsh gas will be comparatively slow. It often happens that a feeder in the roof or other high point of the workings gives off gas more quickly than diffusion can take place where the air-current is sluggish. This results in the accumulation of a body of pure marsh gas at this point. In like manner, we often have a accumulation of a large body of carbonic-acid gas, or blackdamp, near the floor or other low place in the mine workings, where the air-current is sluggish and where the blackdamp is formed quicker than diffusion take place. place.

Limit of Diffusion.—The diffusion of gases continues to take place until the mixture of the gases is uniform. It is a curious fact that this takes place earlier or quicker in the case of gases whose densities differ widely, than where the densities of the two gases are nearly alike. Thus, saturation will take place more quickly in the diffusion of carbonic-acid gas into air than in the diffusion of firedamp into air, although the rate of diffusion of the latter is greater than of the former, firedamp being lighter than carbonic-acid gas.

The property of diffusion is of the greatest importance in the ventilation of mines, since it is owing to this that the air-current is enabled to sweep away these gases from their lurking places in the workings more rapidly

and effectually than it otherwise could.

Transpiration of gases is the exuding of the gases from the pores of the coal in which they are contained. It is a well-known fact that transpiration takes place more rapidly from a newly exposed face of coal. This is owing to the fact that the gas pent up in the coal, or occluded in the seam, tends to escape at the first opportunity, when the seam is exposed to the atmosphere. The gas is under a certain pressure, as we have previously observed, and, as the mine workings penetrate the coal seam, the gases are forced outward from the coal by their own pressure, thus expanding into the air of the mine.

The transpiration of gas from coal seams differs very widely, in some seams it being so rapid and violent as to splinter and break the coal in its effort to escape. It frequently causes a crackling sound peculiar to a very gaseous seam, and in some cases, causes fine coal to be thrown into the face

of the miner.

GASES FOUND IN MINES.

Oxygen O is a colorless, odorless, tasteless, non-poisonous gas. It is heavier than air, having a specific gravity of 1.1056. It is the great supporter of life and combustion. Oxidation, or the union of any of the elements with oxygen, is simply another term for combustion in its broadest sense. forms of matter containing carbon are easily decomposed at certain temperatures, through carbon seeking to combine with the oxygen of the air to form carbonic-acid gas CO₂. This union of the oxygen with other elements, or oxidation, takes place at all temperatures. It is less active when the temperature is low, and is then known as slow combustion. An example of The fine coal that is so often thrown back into the gob is acted on first by moisture, and as its temperature rises, carbonic-oxide gas is formed in small quantities by the union of the carbon of the coal with the oxygen of the air, as the temperature rises, more gas is formed. Heat is caused by the chemical carbon dure that it is the character of the carbon of th action due to the interchange of the atoms, this heat being often sufficient to ignite the gas formed, spontaneous or active combustion resulting. Oxygen is the element in the atmosphere on which all life depends.

Nitrogen N is a colorless, odorless, and tasteless gas; it is neither combusnitrogen is a coloriess, odoriess, and casceless gas, it is not poisonous, and is lighter than air, having a specific gravity of 9713. Nitrogen is a particularly inert gas; it takes no active part in any combustion, in the sense of causing such combustion. Its province is to dilute oxygen of the atmosphere, on which life depends. Were it not for this dilution, oxidation would be too rapid, and not as completely under control as at present. The effect of nitrogen on human life would be to suffocate, if breathed pure, inasmuch as it would exclude oxygen from the lungs. Nitrogen itself has no life-giving power.

Mersh gas CH, often called light carbureted hydrogen, or methane, is a

chemical compound, consisting of 4 atoms of hydrogen to 1 atom of carbon.

one of the chief gases occluded in coal seams, and results from the morphism of the carbonaceous matter from which coal is formed, when metamorphism has taken place with the exclusion of air, and in presence ater. Pure marsh gas is colorless, odorless, and tasteless, and is lighter ater. Pure marsh gas is colorless, odorless, and tasteless, and fa lighter air. Its specific gravity is .559, and it diffuses rapidly in the air, forming edamp mixture. Marsh gas burns with a blue flame, but it will not cort combustion, and a lamp placed in it is immediately extinguished. It may be it it is a difficult matter to place a lamp in a body of pure marsh since the gas diffuses so rapidly that a firedamp mixture always surds a body of pure gas, which may exist high up in some cavity of the, or at the face of a steep pitch where the circulation is slow and the er at the face is giving off a large amount of gas. The flaming of lamp in passing through a firedamp mixture would at once cause the adrawal of the lamp before reaching the body of pure marsh gas. But d a lamp be placed in a body of pure marsh gas, it would be extinguished nor. Marsh gas is not poisonous, and when mixed with at in sufficient portion, it may be breathed for a considerable time with impunity (see damp). Pure marsh gas does not support life, but suffocates by exclugo xygen from the lungs.

goxygen from the lungs.

Ither Hydrocarbons.—All gases that are compounds of carbon and hydrogen called hydrocarbons. Of these, the chief member is marsh gas, or light pureted hydrogen, described in the preceding paragraph; the other trocarbons are called heavy hydrocarbons. The chief of these are olefant $C_{2H_{**}}$, and ethane $C_{2H_{**}}$. Both of these gases, like marsh gas, are the alt of the metamorphism of carbonaceous matter, during the formation of coal, but unlike marsh gas, they have been produced in the absence of er, and as a result they contain a larger percentage of carbon than rsh gas. They always exist in common with marsh gas, as occluded gases coal seams, but to a far less extent. Each of these gases possesses a higher minating power, burning with a brighter flame than marsh gas. This is to the larger percentage of carbon present in their composition. Their maining properties are very similar to the properties given for marsh gas; y, however, when present in a firedamp mixture, lower the temperature ignition, and render the mixture more dangerous than it would be erwise.

Constants for Mine Gases.—The following table shows the symbols, specific vities, and relative velocities of diffusion and transpiration of the principal ne gases, arranged in the order of their specific gravities, air being taken as 1. e values given in the next to the last column of this table were ained by experimenting with the gases, and agree quite closely with calculated values given in the preceding column. From this column see that 1,344 volumes of marsh gas will diffuse in the same time as 1,000 umes of air, or 812 volumes of carbonic-acid gas.

TABLE OF MINE GASES,

Name of Gas.	Symbol.	Specific Gravity.	1 V Sp. Gr.		Relative Velocity of Transpiration. (Air = 1.)
		1.00000	1.0000	1.000	1.0000
rbonic acid phureted hy-	CO_2	1.529	.8087	.812	1.2371
rogen	H_2S	1.1912	.9162	.95	
ygen	Ō	1.1056	.9510	.9187	.903
flant	C_2II_4	.978	1.0112	1.0191	1.788
rogen	N	.9713	1.0147	1.0143	1.0303
rbonic oxide	`co	.967	1.0169	1.0149	1.034
am	H_2O	.6235	1.2664	1	
rsh gas	CH ₄	.559	1.3375	1.344	1.639
drogen	H	.06926	3.7791	3.83	2.066

Carbonic-oxide gas CO, often called whitedamp, is a chemical compound unsisting of 1 atom of carbon united to 1 atom of oxygen. To a certain

extent it occurs as an occluded gas in coal. It is chiefly formed, however in coal mines, by the slow combustion of carbonaceous matter in the gob waste places of the mine, where the supply of air is limited. It is always product of the slow combustion of carbon in a limited supply of air. therefore one of the chief products of gob fires, and is also a product of explosion of powder in blasting. This gas often fills the crevice mabehind a standing shot, and causes the flash that takes place when the content of the co This gas miner puts his lamp behind such shot to examine the same. formed in large quantities whenever the flame of a blast or explosion projected into an atmosphere in which coal dust is suspended. The force a blast often blows the dust into the air, and the flame acting on it dis

carbonic-oxide gas. Carbonic-oxide gas is lighter than air, having a specific gravity of .9 and it therefore accumulates near the roof and in the higher works places. It is colorless, odorless, and tasteless. It is combustible, burnt with a light-blue flame. This is the flame often seen over a freshly fit anthracite fire. It is also a supporter of combustion, being the only min gas, that burns and also supports combustion. This property leads to very important results in mines, inasmuch as it lengthens the flame of a lamp or Important results in mines, inasmuch as it lengthens the flame of a lamp of the flame of a blast. Any flame is fed by this gas, and is thereby transmitted through the mine airways, from one point to another. The same property extends very widely an otherwise local explosion. This gas has the widest explosive range of any gas known to mining, except hydrogen. The effect of its presence in firedamp mixtures is always to widen the explosive range of the firedamp, causing it to become explosive in larger and smaller proportions than it otherwise would. Carbonic-oxide gas is a very poisonous gas, and acts on the human system as a narcotic, producing drowsiness or stupor, followed by acute pains in the head, back, and limbs, and afterward by delirium. It acts, when breathed into the lungs, to absorb the oxygen from the blood, or, in other words, poisons the blood.

Carbonic-oxide gas is detected in mine workings by its effect on the flame of a lamp, which burns more brightly in the presence of the gas, and reaches

of a lamp, which burns more brightly in the presence of the gas, and reaches

upwards as a slim, quivering taper, having often a pale-blue tip that, however, is not readily observed. Garbonic-acid gas CO₂, often called blackdamp or chokedamp, is a chemical compound consisting of 1 atom of carbon united to 2 atoms of oxygen. heavier than air, having a specific gravity of 1.529. It therefore accumulates near the floor or in the low places of the mine workings. It is always the result of the complete combustion of carbon in a plentiful supply of air, and is a product of the breathing of men and animals, burning of lamps, or any other complete combustion. It is always present in occluded gases.

Carbonic acid gas is a colorless, odorless gas, but possesses a peculiarly sweet taste, which may be detected in the mouth when it is inhaled in large quantities. It is not combustible, nor is it a supporter of combustion. Lamps are at once extinguished by it. It diffuses slowly into the atmosphere, and is a difficult gas to remove in ventilating. It is not poisonous, but acts to suffocate by excluding oxygen from the lungs. Its effect, when breathed for any length of time, is to cause headache and nausea, followed by weak-ness and pains in the back and limbs; when present in larger quantities, it causes death by suffocation. This gas, when present in firedamp mixtures, has the opposite effect from that of carbonic-oxide gas, inasmuch as it narrows the explosive range of the firedamp, and renders such mixtures inexplosive, which would otherwise be explosive (see Firedamp).

Carbonic-acid gas is detected in the mine air by the dimness of the lamps and by their extinguishment when present in larger quantities. It should always be looked for at the floor, and in low places of the mine workings. Sulphureted hydrogen H₂S occurs at times as an occluded gas in coal seams, but more often exudes from the strata immediately underlying or over-

lying those seams. It is generally supposed to be formed by the disintegra-tion of pyrites in the presence of moisture. It is heavier than air, having a specific gravity of 1.1912. It is a colorless gas, having a very disagreeable odor resembling that of rotten eggs, and is known to the miners as stinkdamp. It is an exceedingly dangerous gas when occurring in considerable quantities. When mixed with 7 times its volume of air, it is violently explosive. It is extremely poisonous, acting to derange the system when breathed in small quantities, and, when inhaled in larger quantities, it produces unconsciousness and prostration. Its smell serves as the best means for its detection.

redamp.—The general term firedamp relates to any explosive mixture of sh gas and air, although in some localities this term is understood as ring to any mixture of marsh gas and air whatever, whether explosive therwise. Many persons speak of pure marsh gas as firedamp. The first

ning given above, however, is the general acceptation of the term.

"Ure marsh gas when present in small quantities in the air burns in the continuous marsh gas is eased, the effect on the flame of the lamp is at once noticeable. As the eased, the effect on the flame of the lamp is at once noticeable. As the cortion of gas in the air is further increased, and approaches the lower losive limit, the lamp flame enlarges, snaps, and crackles. When the cortion of gas to air is 1 to 13, slight explosions occur within the lamp, flame of the lamp jumping violently. As the proportion of gas is eased, the violence of the explosion is augmented until it reaches a simum, when the proportion of gas to air is 1 to 94 (exactly, 1:9.38). Is is the proportion of gas and air in firedamp, when at its maximum closive violence. From this point, as the quantity of gas is still further reased, the violence of the explosion decreases, until it becomes very ole when the proportion of gas and air is 1 to 54, and ceases altogether ond this point. The explosive limits of marsh gas, or the limits of firenp mixtures, are then as follows: Lower limit, 1 volume of gas to 13 umes of air, higher limit, 1 volume of gas to 54 volumes of air. These its refer to pure firedamp, or, in other words, a firedamp mixture coning of pure marsh gas and air.

It rarely happens that firedamp, as found in mine workings, is pure, but takins admixtures of other gases, such as carbonic-acid gas CO2, carbonic-

itains admixtures of other gases, such as carbonic-acid gas CO_2 , carbonic-

de gas CO, and heavy hydrocarbons.

Afterdamp.—The term afterdamp relates to the gaseous mixture that exists mine workings after an explosion of gas. The composition of afterdamp exceedingly variable, and admits of no general analysis that can be plied with certainty to any one explosion. The conditions that obtain an explosion are so manifold, and control so completely the character of gases formed, that it is impossible to give more than a general analysis afterdamp.

The chief products of the complete explosion of pure firedamp are carnic-acid gas, watery vapor, and nitrogen (see page 343). The explosion of odamp is seldom, however, complete. Where a large body of gas has ploded, the air-current in the mine workings does not furnish sufficient for the complete combustion of the firedamp, and as a result, a large for the complete combustion of the iredamp, and as a result, a large count of carbonic-oxide gas is formed, and is present in the afterdamp of explosion. The presence of this gas (CO) renders the afterdamp far ore dangerous than it would otherwise be, for two reasons: The gas itself very poisonous, and its presence is not at once detected by the zealous on that are working to rescue their fellow workmen. The lamps burn ry brightly in this gas, and the rescuers press forward unconscious of their all danger until overcome by the effects of the gas. The presence of coal st in suspension in the mine air at the time of the explosion, or thrown to the air by the force of the explosion, results at once in the production alarge amount of carbonic-oxide gas. It is a well-known fact, also, that a large amount of carbonic-oxide gas. It is a well-known fact, also, that rbonic-acid gas CO_2 , formed as a direct product of the explosion, or which we present in the mine air before the explosion, coming in contactth the incandescent carbon of the coal dust, is converted by it, at the high mperature of the flame, into carbonic-oxide gas CO. We observe, therere, that an explosion, in all its effects, tends to the rapid and abundant oduction of this most dangerous gas.

The other products of an explosion are numerous, but for the larger part, dimportant, except as they do not support life. We have mentioned and scribed only those gases forming the larger portion of the afterdamp, or

nstituting the active agents in an explosion.

Occurrence of Gases in Mines.—Most of the gases occurring in mines are
cluded in the coal or the strata adjacent to the coal seam. These occluded ses differ widely in different coals, but are chiefly marsh gas with varying antities of heavy hydrocarbons (olefant gas, ethane, etc.) and carbonicid gas to a limited extent. In some coals, a large percentage of nitrogen
s is occluded, which, however, transpires very slowly into the atmosphere.
ilphureted hydrogen, when present, usually exudes from the underlying
overlying strata of the coal seam. These occluded gases are the result of
al formation, according to the best authorities and evidence. They exist the pores of the coal under considerable pressure due to the weight of the superincumbent strata. When the strata adjacent to the coal seam a impervious to gases, the occluded gases remain pent up, and we have we is called a gaseous seam. The tendency of the gas is always to escape to the companion of the gas is always to escape the gas is always to escape to the companion of the gas is always to escape to the gas is always to escape the gas is always to escape the gas is always to escape the gas is always the gas

surface or into the mine workings, at the first opportunity.

These gases have each their separate effects and their combined effects sometimes very complicated. We can only study to become familiar will the separate characteristics of each of these gases, and judge of their combined effect when present in firedamp mixtures. For example, one effect all these gases when present in firedamp mixtures is to dilute the firedam and to that extent weaken its explosive force. Dilution of the firedamp carbonic-acid gas CO₂ decreases very rapidly the explosiveness of the firedamp. When carbonic-acid gas is present in firedamp to the extent of on seventh its volume, explosion ceases altogether; in other words, tifredamp is rendered inexplosive. The effect of smaller quantities of tags is to contract the explosive limits of the firedamp as well as to weak the explosion. The effect of carbonic-oxide gas CO when present in fidamp mixtures is likewise to dilute the firedamp. The flame, however, lengthened by this gas, and the explosive limits of the firedamp mixture suidened. In other words, mixtures of marsh gas and air, which were a explosive mixtures, are rendered explosive by the presence of carbonic oxide gas.

The chief source of the other mine gases lies in the slow combustion of carbonaceous matter in the gob, gob fires, burning of lamps, breathing of men and animals, etc. The table on page 353 shows the percentage of occluded gases in a number of coals and their volume at normal temper-

ature and pressure.

Gas Feeders (Pockets).—The occluded gas of a coal seam escapes whenever opportunity is offered, and accumulates in the pockets and crevices of the adjoining strata, forming what are called gas feeders. These constitute a very dangerous element in the mining of gaseous seams, inasmuch as when such a crevice or feeder is tapped by the miner's drill, the gas, which is usually under heavy pressure, blows out in a large volume, at times even blowing the drill from the hole.

Pressure of Occluded Gases.—Occluded gases exist under a pressure that is proportionate to the weight of the overlying strata. Numerous experiments in England, France, and Belgium show that the pressure of gases occluded in coal seams frequently amounts to from 10 to 16 atmospheres, and in some cases has reached 32 atmospheres. These high pressures of occluded gases manifest themselves frequently in the boring of gas wells, where the tools

are at times blown from the bore hole.

PRESSURE OF OCCLUDED GAS.

Name of Mine.	Depth of Hole. Feet.	Pressure Pounds.
Elmore mine, main bed	8.53	4.36
Hetton mine, Hutton bed	8.98	6.96
Eppleton mine, Hutton bed	46.90	36.14
Balden mine, Bensham bed	31.85	71.41
Harris Navigation mine	32.80	22.04
Merthyr Vale mine	49.20	39.67
Celynen mine	54.48	68.32
Harton mine (1,214 ft. deep)	16.24	196.30
Harton mine	27.55	230.44
Harton mine	37.13	294.45

Amount of Gas.—Experiments made by the Prussian Firedamp Commission have given results varying from 357 to 2,400 cu. ft. of gas liberated per ton of coal mined. Mr. Chesneau gives 1,377 cu. ft. at the Herin mine, Anzin. Experiments at the Ronchamp mines give 883 cu. ft.

Outbursts of gas are frequent occurrences in some coal seams. They are caused by the occluded gas finding its way to a vertical crevice or cleat in the

GASES ENCLOSED IN THE PORES OF COAL AND EVOLVED IN VACUO AT 212° F.—(Thomas.)

						Qua	ntity.
Name of Colliery.	Quality.	CO2	o	CH4	N	c. c. per 100 Grams.	Cu. Ft. per Short Ton.
vigation	Steam.	13.21	.49	81.64	4.66	250.0	
nraven	Steam.	5.46	.49	84.22	9.88	218.0	80 70
	Steam.	18.90	1.02	67.47	12.61	147.0	47
te	Steam.	9.25	.34	86.92	3.49	375.0	120
nville's Court	Anthracite.			93.13	4.25.	555.0	178
tney's	Anthracite.	14.72	ļ	84.18	1.10	600.0	192
vmouth Iron Works	Bituminous.	36.42	.80	1	62.78	55.9	18
m Clydach	Bituminous.		1.05	63.76		55.1	18
ttwys	Bituminous.		6.09	2.68	69.07	24.0	8

Gases Enclosed in the Pores of Coal and Evolved in Vacuo at $212^{\rm o}$ F.— $(H.\ LeChatellier.)$

Locality.	CH ₄	CO2	N	0	Analyst.
unraven mine (blowers) unraven mine (bore hole) srswood mine arswood mine (blowers) amorgan mine (blowers)	96.70 96.50 84.16 88.86 93.01	.47 .44 .86 .41 .27	2.79 3.02 12.30 8.90 5.94	2.65 1.83 .78	J. W. Thomas. J. W. Thomas. W. Kellner. W. Kellner. W. Kellner.
arwin mine (blowers)	95.11 94.59	.18	4.07 4.48	.34 .75	Austrian Firedamp Commission.
arwin mine (blowers) ruschau mine ruschau mine(blowers)	99.10 79.16 87.93	.20 .19 .83	.70 17.04 10.25	.61 .99	
eterswald mine (blowers) egen Gottes mine	90.00 83.51	.15 1.17	9.25 15.02	.60 .30	Sauer.
egen Gottes mine (borehole) jebe Gottes mine (borehole)	87.16 77.69	1.11 3.77	11.73 18.48	.06	Sauer. Sauer.
lebe dottes mine (borenoie)	17.05	5.77	10.40	.00	Sauer.

Gases Enclosed in the Pores of Coal and Evolved in Vacuo at 212° F.—(Schondorff.)

Locality.	CH ₄	C_2H_6	H	CO2	N+O
Blowers. onifacius mine at Kray (Essen) onsolidation mine at Schalk (Westphalia) önig mine at Neunkirchen (Saarbruck) berkirchen mine at Schaumburg	90.94 89.88 84.89 \$60.46 \$93.66	1.62 37.64 .88	1.40 5.84 2.11	.30 .67 .65 2.56 .63	7.36 3.61 12.84 4.80
avities in the roof. Lothringen mine at Castrop (Westphalia) (ew Iserlohn mine at Lawgendren (West- phalia)	$ \begin{cases} 27.95 \\ 4.75 \\ 4.00 \end{cases} $.06	1.35 .09	.45 1.34 .40	70.25 65.00 95.00

coal seam, as illustrated in Fig. 2, and the pressure of the gas thus become distributed over a large area. Thus, a pressure of 10 atmospheres of a g feeder becoming distributed over an area of 200 sq. ft. results in a total pressure of upwards of 2,000 tons, upon a comparatively small area of coal

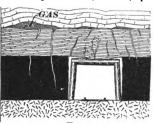


FIG. 2.

As mine openings approach proximit to such a locality, this pressure man ifests itself by bursting the coal from its position in the face, and throwin it into the entries, in some cases com pletely blocking the openings or past Such an occurrence be outburst. It is frequently sageways. termed an outburst. thunderings and accompanied by thunderings and poundings, which manifest themselves for several days previous to the actual outburst of gas. These poundings are taken as a warning by the minera experienced in such regions. The poundings are probably the result of the gas working its way from one cravite to another always advancing. accompanied by crevice to another, always advancing

closer and closer to the mine openings, where they finally burst forth with extreme violence.

Testing for Gas by Lamp Flame.—Marsh gas and firedamp are detected in mine workings by the small flame cap that envelopes and surmounts the flame of the lamp in a firedamp mixture. This flame cap is caused by the gaseous mixture, which burns as it comes in contact with the flame. The proportion of gas in the mixture determines the height of the flame cap. When testing for gas, the lamp flame is first reduced to a small, uniform size, and although this is not a universal practice, it has the advantage of The lamp is held in an upright position, in one giving uniform results. hand, while the eyes are carefully screened by the other hand from the glare of the light, the lamp being slowly raised toward the roof where gas is The flame is carefully watched for the first appearance of a cap. suspected. and the height of the cap is carefully noted. Many lamps are provided with a graduated scale set opposite to the flame, so that the height of a cap may be estimated with accuracy. After the observation, the lamp is quietly and promptly withdrawn from the gas. Should faming occur within the lamp, as sometimes happens when it is raised too quickly, or when the gaseous mixture is strong, the lamp should be withdrawn carefully and not with undue haste, as there is danger of the flame of the gases burning within the lamp being forced through the gauze by a rapid movement. This requires great presence of mind on the part of the person using the lamp.

In Fig. 3 the heights of flame cap due to the presence of different proportions

of marsh gas are shown. These heights, as given, refer to the experimental heights of flame cap obtained with pure marsh gas. It should be observed, however, that the presence of other gases in the firedamp will vary its explosive character, and this fact very materially modifies the explosiveness of certain caps. For example, in the experiments on pure marsh gas, a 2" flame cap was found to be inexplosive; while, in the mine, and

1:50 1:40 1:30 1:20 1:25 1:16

FIG. 3.

with the variable character of the firedamp mixtures usually found there, a flame of 1½ in. is often found to indicate explosive conditions. Again, flames of even less height than this often indicate dangerous conditions, especially where the coal is inflammable and there is much fine dust present in the atmosphere. These conditions account readily for the various statements that we companyly see it record to the various extatements. that we commonly see in regard to the explosiveness of certain flames. fact, each fire boss learns, after years of experience, to depend wholly on his

own knowledge, guided by the conditions that exist in the workings and with which he has become familiar.

SAFETY LAMPS.

The safety lamp is designed to give light in gaseous workings without the danger of igniting the gases present in the atmosphere. The principle of the safety lamp depends on the cooling effect that an iron-wire gauze exerts on flame. It is a well-known fact that all gases ignite at certain fixed temperatures, and if this temperature is decreased from any cause, the flame is extinguished.

Use of Safety Lamps.—Safety lamps are used for two general purposes in

the mine, and may be classified under two heads: (a) lamps for general use;
(b) lamps for testing for gas.

Safety Lamps for General Work.—The essential features of a lamp designed for general mine work are: (1) safety in strong currents; (2) good illuminating power; (3) security of lock fastening; (4) freedom from flaming; (5) security against accident; (6) simplicity of construction. The conditions under which a lamp is placed at the working face differ from those that attend the testing for gas. The illuminating power of the lamp must be good, so that the workman can see clearly what he is doing. The lamp must not be too sensitive to gas, or its tendency to flame will necessitate that a careful watch be kept of it, and this would interfere with the prosecution of the miner's work. Again, the miner is too often careless or neglectful of his lamp, and would fail to give it the required attention. The lamp is often upset, and is apt to be broken by flying coal, or by a fall, unless carefully protected. The lamp should be so securely locked as not to permit of any tampering on the part of the miner without its being detected in the lamp room. In order that the lamp may be thoroughly and rapidly cleaned, its construction should be simple. The lamp should be easily taken apart and put together again after it is cleaned.

are: (1) free admission of air below the flame; (2) no reflecting surface behind the flame; (3) ability to test for a thin layer of gas at the roof. When testing for gas, it is important to have a free admission of the air below and around the flame, as the flame cap is very sensitive and is interfered with seriously by the conflicting ascending and descending currents in a lamp in which the air enters above the flame. A more uniform cap the be given where the currents ascend quietly around the flame. This feature is very important to the production of a good flame cap, and it is this feature that makes the Davy lamp such a favorite among fire bosses. In order that a flame cap shall be readily observed, there should be no reflection behind it, as the eye is easily deceived under these conditions. A scale by which the height of the flame cap may be accurately measured, is a convenient

the neight of the name cap may be accurately measured, is a convenient feature in many lamps for testing purposes.

In the use of the common Davy lamp in testing for gases, it is a common, although dangerous, practice to turn the lamp on its side and place it close up against the roof. In this position, the flame is very apt to pass through the gauze, from two causes: The gauze is readily heated, because the flame cap is close against it, and when heated, affords no protection against the passage of the flame and the ignition of the gas outside the lamp. Again, in this position, small particles from the roof are apt to fall upon the gauze, and this may often assist in the passage of the flame through the gauze. A dirty gauze is unsafe. When the lamp is turned sideways, the gauze may become smoked by contact with the flame, and this smoke, or deposit of carbon, assists greatly the passage of flame through the gauze. common and dangerous practice on the part of the fire boss, is to brush the gas down on the lamp with his cap. By so doing, there is great danger of the flame being blown through the gauze and igniting the gas that may be present. On these accounts, it is essential that a good lamp for testing purposes shall be able to draw its air from a point close to the roof, in cases where it is necessary to do so. This is often accomplished by an extra tube, which is supplied with the lamp, and which may be taken off the lamp when not in use. This tube extends up the outside of the lamp to the top. An important feature of a lamp for testing purposes is the uniformity of its flame. A more uniform flame is obtained in the use of alcohol instead of

the lard oil commonly used in the safety lamp.

Detection of Small Percentages of Gas.—The Davy lamp in the hands of a careful person may be made to detect the presence of gas in quantities allow as 3%. It is claimed by some fire bosses that 2% of gas may be detected with a good Davy. For the detection of small quantities of gas, specially constructed lamps have been used. These lamps are designed to burn alcohol or hydrogen, giving a non-luminous flame. Among these may be mentioned the Pieler lamp, burning alcohol, which it is claimed will detec as small a quantity of gas as ½. A device known as the Clowes gas teste has been invented, and may be attached to many safety lamps. It considered to the lamp flame when testing for gas. Surrounding the wick of the lamp is a closely fitting cone, to which the hydrogen from the tube is supplied. When the lamp is to be used for testing for gas, the wick is lowered, extinguishing the oil flame after the hydrogen is turned on. It is claimed that gas may be detected in as small quantities as ½ by this apparatus attached to any good safety lamp admitting its air below the flame.

The Shaw gas tester is useful for determining the percentage of marsh

The Shaw gas tester is useful for determining the percentage of marsh gas in the mine air, but it cannot be applied at the face, and samples of gas

must be taken to the surface for analysis.

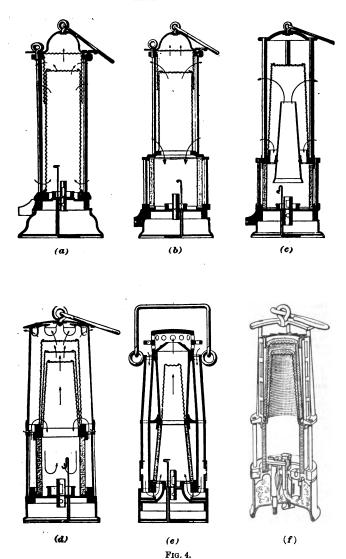
Oils for Safety Lamps.—Most safety lamps burn vegetable oils, which are considered the safest for mining use, and so reported by the English Mine Commission. Such oils are rape-seed oil and colza oil, made from cabbage seed. Seal oil is also largely used, and was regarded as a safe oil by the English Mine Commission. Seal oil affords a better light than vegetable oils, and in its use there is less charring of the wick. A mixture of 1 part of coal oil to 2 parts of rape or seal oil is often used, and improves the light, but the smoke from the flame is increased. The Ashworth-Hepplewhite-Gray lamp is constructed to burn coal oil, or a mixture of coal and lard oil. The Wolf lamp is especially designed for burning naphtha or benzine. Special tests have been made to prove the safety of using such a fluid in this lamp, and resulted in demonstrating the fact that the lamp was safe under any conditions that might arise. A thorough test was made, the oil vessel of the burning lamp being heated to 180° F., at which point the lamp was extinguished without manifesting any dangerous results.

extinguished without manifesting any dangerous results.

Types of Safety Lamps.—In the year 1815, Sir Humphrey Davy and George Stevenson, the latter a poor miner, discovered, simultaneously, that flame would not pass through small openings in a perforated iron plate. This led to the construction of what are known as the Davy, and the Stevenson or "Geordy," lamps. The Davy lamp is still a great favorite among fire bosses for the detection of gas in mine air. Inasmuch as all safety lamps, of which there are a large number, depend on the same principle, we will only describe such lamps as possess essential features, and which show important improvements and the gradual developments in safety-lamp construction.

Davy lamp.—Fig. 4 (a) shows a wire gauze cylinder about 5 in. in height and 14 in. in diameter, surmounted by a gauze cap 2 in. in depth. The gauze, which has 28 wires to the inch, or 784 apertures to the square inch, is fastened to a brass standard, which secures it to the oil cup or lamp below. The gauze at the top of the lamp is doubled by the cap, which gives greater security at this point, where the flame tends to pass through the gauze more quickly, and where the gauze is more readily burned out. The mixture of gas and air enters the lamp in the lower part of the gauze, and burns within the lamp, the products of combustion passing out through the upper portion of the gauze cylinder. This lamp gives a good flame cap, on account of the free access of the air below the flame, which prevents smoking and increases the illuminating power of the lamp. As a lamp for general use, the Davy lamp, however, is unsafe, on account of its liability to flame. In many mining localities the use of this lamp is prohibited by law, except for purposes of examining for gas, when it must be used solely by properly authorized fire bosses. The flame of the lamp is also unprotected from the force of rapid air-currents, and is not safe when the velocity of the current exceeds 6 ft. per second. The illuminating power of the lamp is also not sufficient for general work.

Clanny Lamp.—The unbonneted Clanny lamp, Fig. 4 (b), is constructed according to the same principles as the Davy lamp, differing only in the fact that the lower part of the wire gauze surrounding the fame is replaced by a strong glass cylinder or chimney. The purpose of this is to increase the illuminating power of the lamp. The lamp, when clean, gives a good light, but the entrance of the air at a point above the flame, and its descent



within the lamp to the flame, causes the lamp to smoke, due to the conflict of the ascending and descending air-currents within the lamp. The smoke becomes deposited on the glass chimney, which interferes greatly with the light. This lamp is not a good one for gas testing, and in fact cannot be used for that purpose to any advantage. The unbonneted Clanny is not safe in an air-current having a velocity greater than 8 ft. per second. The bonneted Clanny obviates this difficulty to a large extent, but increases the

tendency of the lamp to smoke. Musseler Lamp.—This lamp, Fig. 4 (c), in all respects resembles the Clanny lamp just described, except that the tendency in the Clanny lamp to smoke is overcome in the Mueseler by increasing the draft by means of an interior wrought-iron chimney or tube, supported within the lamp, and reaching down to within an inch of the base of the flame. The air enters the lamp as in the Clanny, above the flame, but is deflected downwards by the central tube, and passes under the edge of this tube, ascending through it to the top of the lamp, where it escapes. The Mueseler lamp is a better lamp for illuminating purposes than the Clanny, and presents more security, when bonneted, against explosions within the lamp. This lamp will withstand a current of very much higher velocity than the Clanny lamp, and is reputed to be safe in a current having a velocity of 100 ft. per second. The lamp is not a good lamp for the detection of gas. It does not flame, however, as quickly as the Clanny lamp.

Marsaut Lamp.—This lamp, Fig. 4 (d), is built after the Clanny lamp in every respect, but is supplied with multiple-gauze chimneys, one within the

other, the effect of which is to increase the security against explosion of gas within the lamp. The bonneted Marsaut lamp is a peculiarly strong lamp in this respect. The gauze used in the caps of this lamp has 334 apertures to

in this respect. The gauze used in the caps of this lamp has \$34 apertures to the square inch. This lamp is often extinguished in an explosive mixture by the force of the explosion within itself. It gives a good light and is a good lamp for general work; it is not, however, a good lamp for testing for gas.

Ashworth-Hepplewhite-Gray Lamp.—This lamp, Fig. 4 (e), combines a number of characteristic features. It is designed for general work, as well as for testing for gas. It often happens that gas accumulates in a thin layer along the roof of an entry or working place, and is not detected by the use of the Davy lamp or any ordinary lamp. The Gray lamp is so arranged that it can be made to draw its air from the top of the lamp, by means of openings in the top of the four standards of the lamp, the air passing down through the standards, and into the lamp, below the fiame. When not in use for testing, openings can be made in the lower part of the standards by moving a slide, and air enters at these openings. The lamp is essentially a bonneted Clanny. The glass chimney, however, as well as the gauze tially a bonneted Clanny. The glass chimney, however, as well as the gauze that surmounts it, is made in a conical form, the purpose of this being to diffuse the light upward for examination of the roof of the mine. The conical form given to the gauze also strengthens the lamp against explo-sions of gas within. This lamp is a very good all-around lamp, and possesses good illuminating power.

Wolf Lamp.—The Wolf lamp, Fig. 4 (f), is rapidly growing in popularity

having been already introduced in a large number of mines in America and England, and on the Continent. This lamp is essentially a Clanny lamp with a free admission of air. It is compact and efficient, and has good illuminating power, and is also constructed in different forms, combining, as desired, any or all of the features of previous lamps. Two of its characteristic features, however, consist in a self-lighting arrangement accom-plished by means of a percussive device, which ignites a wax taper within the lamp, and a locking device, which can be opened only with a powerful magnet. This relighting device is an important feature in any safety lamp for general use, inasmuch as the most dangerous conditions exist immediacted after an explosion, and the miners are always left to grope their way in the dark. A large number of lives are lost, owing to the confusion that ensues, the men becoming bewildered and losing their way, when they are shortly overcome by the afterdamp of the explosion. This lamp permits of immediate relighting with safety to the men.

Locking Lamps.—The ordinary lock consists of a lead plug, which, when inserted in the lamp, will show the least tampering on the part of the Other locks consist of an ordinary turnbolt operated by a peculiar key. Magnetic locks allow of the opening of the lamp only by means of a

strong magnet kept in the lamp room.

Cleaning Safety Lamps.—Safety lamps should be thoroughly and regularly

cleaned and filled between each shift. Each lamp should then be lighted and inspected by a competent person before being given to the miner. A careful inspection of the gauze of the lamp is necessary, as well as of all the joints by which air may enter the lamp. It should be known to a certainty that each lamp is securely locked before leaving the lamp room.

Relighting Stations.—These stations are located at certain places in gaseous.

mines where they can be supplied with a current of fresh air, and where there is no danger from the gases of the mine. The lamp is apt to be overturned, or to fall, and is often extinguished thereby; and if these stations were not provided, the man would have to return with his lamp to the surface in order to have it relighted. Such a station is always located at the entrance of the gaseous portion of a mine, in cases where the entire mine does not liberate gas.

Illuminating Power of Safety Lamps.—The following table gives the illuminating power or candlepower of some of the principal lamps. The light of a

sperm candle is taken as 1, or unity.

Name of Lamp.	Illuminating Power of Lamp.		
Davy Geordy Clanny Mueseler Evan Thomas Marsaut, 3 gauzes Marsaut, 2 gauzes Marsaut, bith Howat's deflector Ash worth-Hepplewhite-Gray Wolf	.16 .10 .20 .35 .45 .45 .55 .65 .65		

EXPLOSIVE CONDITIONS IN MINES.

In the ventilation of gaseous seams, the air-current may be rendered explosive by the sudden occurrence of any one of a number of circumexplosive by the sudden occurrence of any one of a number of circumstances that cannot be anticipated. Among these are the following: (1) Derangement of the ventilating current. (2) Sudden increase of gas due to outburts, falls of roof, feeders, fall of barometric pressure, etc. (3) Presence of coal dust thrown into suspension in the air, in the ordinary working of the mine, or by the force of blasting at the working face, or by a blown-out, or windy, shot. (4) Pressure due to a heavy blast, or any concussion of the air caused by closing of doors, etc. (5) Rapid succession of shots in close workings. (6) Accidental discharges of an explosive in a dirty atmosphere Any or all of these causes may precipitate an explosion at any moment. Hence, the condition of the air-current should be maintained far within the explosive limit. The explosive conditions vary considerably in different explosive limit. The explosive conditions vary considerably in different coal seams. The nature of the coal and its enclosing strata, its friability and inflammability, together with the character of its occluded gases, determine, to a large extent, the explosive conditions in the seam. Experience in any particular seam or district must always be the best guide, and furnish the best standard for determining the explosiveness of any given lamp flame. For example, a 2" flame may be comparatively safe in a small mine where the coal is hard and not particularly flammable, while a 14" flame cap would be considered unsafe in mines where the conditions are more favorable to the generation of gas and formation of coal dust. The daily output of the mine and the general care that is enforced upon the miners at the working face are factors that should always be considered and taken into serious account in determining explosive conditions (see Testing for Gas by Lamp Flame).

Derangement of Ventilating Current.—The flow of the air-current must be uniform and continuous. Doors must be kept closed, since the mere setting open of a door, for a short period of time, is sufficient to precipitate a serious explosion. Any contemplated change in the current, by the erection of brattices, air bridges, stoppings, etc., should be carefully considered before the work is begun, and every precaution adopted to secure the safety of the

men. Derangement of the current may occur through a fall of roof upon the main airway, by which the area of the airway is reduced, which result in the reduction of the quantity of air passing in the mine. If this fall in the noticed at once, serious results may happen. The utmost vigilance therefore required on the part of fire bosses and all connected with mine workings. The failure of the ventilating apparatus is another source the gives rise to the derangement of the current. As a rule, furnaces are not now employed for the ventilation of gaseous seams. There are, however, some furnaces in use in such seams, and these require constant attention lest the fire should burn low. Upon any accident occurring to the ventilating machinery, notice should at once be given to the inside foreman, and the men withdrawn as rapidly as possible.

A sudden increase of gas may occur at any time in a gaseous seam, owing to an outburst, which suddenly yields a large volume of gas and may render the mine air in that section extremely explosive. The men working on the return of such a current must be hastily withdrawn, and all lights extinguished. A heavy fall of coal in the mine workings or in the airways or the tapping of a large gas feeder, produces the same effect in a less degree. The nearer the fall of roof takes place to the face of the workings, the more liable it is to be followed with a large flow of gas, inasmuch as the gas near the face has not had time to drain off, as in the case of old workings. This fact is always true in reference to new workings in a gaseous seam. The gas continues to flow freely for a considerable period, when its flow gradually decreases until it about ceases. When a large feeder has been tapped, it may be plugged for a time, if necessary, but the better practice is to allow it to flow freely and diffuse into the air-current, which should be sufficiently increased to dilute the quantity of gas given off and to render it inexplosive. The men upon the return air should be notified. It is dangerous practice to light these feeders.

When there is a large area of abandoned workings in the mine, any considerable fall of barometric pressure is usually followed by a large outflow of gas from the gobs or waste places of the mine. A fall of 1 in. in 5 hours represents a very rapid decrease of barometric pressure. At all large collieries there is, or should be, a good standard barometer located upon the surface near the shaft. In many cases, these barometers are self-recording, and are often provided with an automatic alarm that gives warning whenever a fall of barometric pressure occurs. This warning should at once be conveyed to the men in the workings, and every precaution adopted to avoid evil results. The fact is fairly well established that a fall of atmospheric pressure is not followed by an outflow of gas from the mine workings for the space of, say, 3 hours after such fall occurs. This statement must be regarded with caution, however, as it largely depends on the condition and extent of the abandoned workings. Where these are full of gas, its expan-

sion affects the condition of the airways much more quickly than in cases where these working places are partly ventilated.

Effect of Coal Dust in Mine Workings.—According to the greater or less flammability of the coal, the presence of fine dust in the airways and workings of the mine becomes a dangerous factor. Certain coals are extremely friable and are reduced readily to fine dust, which is thrown into suspension in the air-current by the ordinary operations of the miners in their work, as well as by the concussion of the air from numerous causes, and by the movement of cars and the traveling of men and animals upon the various hault ways and passageways. For a long time it was questioned whether the presence of dust was a dangerous factor, except where there was also a small percentage of gas in the air. Evidence, however, has well established the fact that coal dust of itself is a dangerous element, and may often be the sole cause of an explosion, when acted upon by a flame of sufficient intensity and magnitude. The action of the flame is to distil carbonic-oxide gas CO from the fine particles of dust suspended in the air. The explosion of the gas thus formed causes a further disturbance and raises a larger supply of dust, which likewise contributes to the liberation of fresh quantities of gas, and thus an explosion is generated and transmitted. Small quantities of marsh gas greatly increase the violence of this action, but explosions in flouring mills and well-ventilated coal bins establish the fact that such occurrences are not dependent on the presence of marsh gas.

Too much faith must not be placed in the use of water by sprinkling for laying the dust. This has a beneficial effect in the immediate vicinity, but a large amount of water is required to render an untidy working place safe

at firing time. Better practice is to allow no accumulations of dust at the

face. This should be regularly loaded out with the coal.

Pressure as Affecting Explosive Conditions.—Gaseous mixtures that are not explosive in the ordinary condition of a mine, often become explosive under the momentary pressure to which they are subjected by heavy blasting, and, in some instances, this may occur from the concussion of the air caused by the quick shutting of a door. In the latter case, however, the explosive condition of the air would necessarily have to be close to the limit, in order for such a slight occurrence to precipitate an explosion. The factor of pressure as increasing the explosiveness of gaseous mixtures should be considered and constantly borne in mind.

Rapid Succession of Shots in Close Workings.—It constantly happens that two, three, or more shots are fired by means of fuse or touch squibs in a single chamber or heading, where the circulation of air is not always the best. The practical effect is that a considerable quantity of carbonic-oxide gas CO is produced by the firing of the first shot, and this gas does not have time to diffuse or become diluted by the air-current before it is fired by the flame of the following shots. An explosion may often be precipitated by such an occurrence, if the workings are at all dusty. Two shots at the most are all

an occurrence, if the workings are at all dusty. Two shots at the most are all that should be fired at one time in a close chamber or heading.

Mine Explosions.—The explosion of gas in a mine usually arises from the ignition of an explosive mixture of gas and air called firedamp, which has accumulated in some unused chamber or cavity of the roof, or in the waste places of the mine, and has been ignited by a naked light, by the flame of a shot, or by a mine fire. The initial force of an explosion is generally expended locally, but the flame continues to feed upon the carbonic-oxide gas generated by the incomplete combustion of the firedamp mixture, and distilled also from the coal dust thrown into the air by the agitation.

At is required to burn this carbonic-oxide gas, this causes the flame to Air is required to burn this carbonic-oxide gas; this causes the flame to travel against the air-current, or in the direction in which fresh air is found. In the other direction, or behind the explosion, the fiame is soon extinguished in its own trail when the initial force of the explosion is expended. The explosion continues to travel along the airways against the current as long as there is sufficient gas or coal dust for it to feed upon, or until its temperature is cooled below the point of ignition, by some cause such as, for example, the rapid expansion of the area of the workings. We observe the chief factor in transmitting an explosion is the presence of carbonic-oxide gas, which lengthens the flame and extends the effect.

The recoil of an explosion is the return of the flame along the path that it has just traversed. In the recoil, the flame burns more quietly, advances more slowly, and travels close to the roof. The evidence found at the point where a recoil took place, or an explosion turned back, has been sufficient to establish the fact that the recoil is caused primarily by a cooling of the temperature, probably caused very largely by an expansion of the area of the airway. Soot is often deposited at this point in considerable quantity, if the action of the flame is not such as to consume it. This fact alone shows the combustion at this point to have been incomplete. Immediately in the rear of the flame is a mixture of carbonic-oxide gas CO, which bursts into flame at the sudden stoppage of the advancing explosion. This is rendered possible by the flow of cold air from the adjacent chambers and workings along the floor of the airway. The flame now retreats, burning the trail of carbonic-oxide gas along the roof, fed by the cold air along the floor.

To Explore Workings After a Serious Explosion.—The shafts or slopes and the ventilating machinery should claim the first attention of those on the surface, and an effort should be made to reach the bottom as expeditiously as nossible. Assistance from neighboring collieries both in the way of

as possible. Assistance from neighboring collieries, both in the way of skilled labor and advice, should also be requested. Should the shaft or slope need repairs before communication between top and bottom is restored, the person in charge on the surface should, in the meantime, see that props of the lengths in ordinary use, brattice boards, brattice cloth, and nails are brought to a convenient place for putting on the cage or car, and he ought also to collect all the tools likely to be required, such as axes, saws, ham-mers, etc. It is also important that rough tracings of the workings be prepared for the use of the leader of each squad of explorers. Officials will understand how useful these will be to those that are penetrating into workings about which every man of his squad may have been heretofore ignorant.

When the explorers have arrived at the bottom and are ready to proceed, there should be for each section, if more than one is operated upon, two

managers, each having his own squad of men, and his own particular duty managers, each naving his own squar or men, and his own paracterist are to do. One may take charge of restoring the ventilation, the inspection of the workings, and the clearing of the roads; the other may appoint and have charge of the bottom man, the conveying of material, and the detailing of stretcher companies where required. They can consult and help each other in every difficulty, but system is necessary if the work is to be done in

the shortest possible time. The manager who has charge of the men in front should appoint two experienced men with good nerves to act as foremen, instructing them to inspect and report to him the condition of the workings within a short radius. He should then form the rest of his men into, say, three squads of three each, who will work together at stoppings or falls until separated by him, or until the end of the shift. Being near the bottom, it will probably be found that all is clear for three or four breast or stoop lengths, and stoppings are required to be put up. Material will be required for this, and when the cage is first sent to the top for it, it should not be kept there to enable the top man to put on a big load, but it should be sent down with all despatch, loaded with a half dozen each of props and brattice boards, with one piece of cloth and nails. This will allow a start to be made, and will prevent the anxious men from worrying over what to them is an unaccountable delay. Larger loads can be sent down in subsequent trips. convenience in carrying, the brattice cloth may be cut in lengths to suit the gangways or headings with 2 or 3 ft. to spare. Squad No. 1 should be detailed to the first stopping. This may be put up with boards at top and bottom and cloth between. If the air-current is strong, a few of the followbottom and cloth between. If the air-current is strong, a few of the following stoppings may be put up by squads No. 2 and No. 3, with cloth only stretched between two props. These can be very rapidly put up and will drive the ventilation forwards, thus allowing the firemen to extend rapidly the area of inspection. These stoppings can be completed by No. 1 detail. In a short time it may become impossible to proceed in this manner. The foul air will in all probability become more difficult to dislodge, and eventually one detail may bobble to proceed. ally one detail may be able to put up stoppings as quickly as the firedampor chokedamp can be carried off. Part of what may be called the ventilating detail can now be transferred to the bearer detail, the duties of the latter having become heavier as the stoppings advanced. It is not an easy task to carry props long distances in a stooping posture, and when to that is added, it may be, the carrying out of the living or dead bodies, the men begin to fag very soon. But the person in charge here must see that the forward party is kept in material for stoppings so that no delay may occur on that account. A system of staging gives relief to the carrying parties.

To conclude with a few general remarks: Let those that have never yet assisted to explore a mine after an explosion be assured of this, that the chief requisites in a leader are a capacity for hard work and the ability to organize his men into a system, however roughly, whereby work will be best forwarded. It will not speed the work to say to a dozen or more men, generally, do this or that, neither is it beneficial to allow all the workmen to discuss matters and suggest plans. Those in charge ought to arrange what is to be done. Anything else results in noise and confusion. And let men that are sent from other collieries take with them their own tools and lamps. Those in charge ought to take note of the position, etc. of bodies found, and of every point which is likely to throw light on the cause or origin of the explosion. This can be more correctly done before the roads are disturbed by dust and travel. These notes might not only be the means of ascertain-ing the cause of explosion, but also of pointing out a way of prevention in

the future.

In no case after an explosion should the air-current of the mine be reversed from its usual course, except only after careful consideration, because of the reliance placed by the entombed workmen on their knowledge of the direction in which the air should be moving; and the reversal of the current may drive the gases of the explosion upon them with disastrous results. Conditions must be allowed to remain as they exist, and the rescuers conform themselves to such conditions in the best manner possible.

QUANTITY OF AIR REQUIRED FOR VENTILATION.

The quantity of air required for the adequate ventilation of a mine cannot be stated as a rule applicable in every case. Regulations that would supply a proper amount of air for the ventilation of a thick seam would be

found to cause great inconvenience if applied without modification to the workings in a thin seam. Likewise, the ventilation of an old mine with extended workings, a large area of which has been abandoned, and in many cases not properly sealed off, will require, naturally, a larger quantity of air per capita than a newly opened mine or shaft. The natural conditions per capita than a newly opened mine or shaft. The natural conditions existing in rise and dip workings, with respect to the gases that may be liberated or generated in those workings, call for the modification of the quantity of air required in each case. For example, dip workings, where much blackdamp is generated, will require a larger quantity of air, or higher velocity at the working face, to carry off such damps; and rise workings, liberating a large amount of marsh gas, will likewise require a higher velocity at the working face. On the other hand, a reversal of these conditions, such as a large quantity of marsh gas being liberated in dip Workings, or a similar amount of blackdamp being generated in rise workings, will require a comparatively low velocity of the air at each respective working place.

Quantity Required by State Laws.—The quantity of air required by the laws of the several States is generally specified as 100 cu. ft. per man per minute, and in many cases an additional amount of 500 cu. ft. per animal per minute is stated. This quantity is in no case stated as the actual amount of air required for the use of each man or animal, but is only the result of experience, as showing the quantity of air required for the proper ventilation of the average mine, based on the number of men and animals employed. The number of men employed in a mine is an indica-tion of the extent of the working face, while the number of animals employed is an indication likewise of the extent of the haulage roads, or the development of the mine. These amounts refer particularly to non-gaseous seams.

The Bituminous Mine Law of Pennsylvania specifies that there shall be not less than 100 cu. ft. per minute per person in any mine, while 150 cu. ft. are required in a mine where firedamp has been detected.

The Anthracite Mine Law of Pennsylvania specifies a minimum quantity of 200 cu. ft. per minute per person. Each of these laws contains modifying clauses, which specify that the amount of air in circulation shall be sufficient to "dilute, render harmless, and sweep away" smoke and noxious or dangerous gases.

Quantity of Air Required for Dilution of Mine Gases.—To determine this requires a knowledge of the quantity of gas generated or liberated in the workings. The quantity of air for dilution should be ample, and should be such as not to permit the condition of the current to approach the explosive

point. The ventilation should be ample at the face.

Quantity of Air Required to Produce the Recessary Velocity of Current at the Face.—This consideration modifies considerably the quantity of air required for the ventilation of thick and thin seams. The velocity of the current is dependent not only on the quantity of air in circulation, but on the area of the air passage. This area is quite small in thin seams, and often very large in thick seams. As a result, the velocity is often low at the face of thick seams, and insufficient for the proper ventilation of the face, although the quantity of air passing into such a mine may be very large. A certain velocity of the current is always required in order to sweep away the gases. This velocity depends on the character of the gases and the position of the workings. Heavy damps are hard to move from dip workings where they have accumulated; and, likewise, lighter damps accumulating at the face of steep pitches are hard to brush away, and the velocity of the current in these cases must be equal to the task of driving out these gases.

ELEMENTS IN VENTILATION.

The elements in any circulation of air are (a) horsepower, or power applied; (b) resistance of the airways, or mine resistance, which gives rise to the total pressure in the airway; (c) velocity generated by the power

applied against the mine resistance.

Horsepower or Power of the Current.—The power applied is often spoken of as the power upon the air. It is the effective power of the ventilating motor, whatever this may be, including all the ventilating agencies, whether natural or otherwise. The power upon the air may be the power exerted by a motive column due to natural causes, or to a furnace, or may be the power of a mechanical motor. The power upon the air is alway measured in foot-pounds per minute, which expresses the units of wor

accomplished in the circulation.

Mine Resistance.—The resistance offered by a mine to the passage of a air-current, or the mine resistance, is due to the friction of the air rubbing along the sides, top, and bottom of the air passages. This friction causes the total ventilating pressure in the airway, and is equal to it. Calling the resistance R, the unit of ventilating pressure (pressure per square foot) p and the sectional area of the airway a, we have, R = p a; that is to say, the total pressure is equal to the mine resistance.

Velocity of the Air-Current.—Whenever a given power is applied against a given resistance, a certain velocity results. For example, if the power st foot-pounds per minute) is applied against the resistance pa, a velocity q (feet per minute) is the result; and since the total pressure pa moves at the velocity q, the work performed each minute by the power applied is the product of the total pressure by the space through which it moves per

minute, or the velocity. Thus, u = (pa) v.

Relation of Power, Pressure, and Velocity.—The relation of these elements of ventilation is not a simple relation. For example, a given power applied to move air through an airway establishes a certain resistance and velocity in the airway. The resistance of the airway is not an independent factor; that is to say, it does not exist as a factor of the airway independent of the velocity, but bears a certain relation to the velocity. Power always produces resistance and velocity, and these two factors always sustain a fixed relation.

This relation is expressed as follows: The total pressure or resistance varies as the square of the velocity; i. e., if the power is sufficient to double the velocity, the pressure will be increased 4 times; if the power is sufficient to multiply the velocity 3 times, the pressure will be increased 9 times. Thus, we observe that a change of power applied to any airway means both a

change of pressure and a change of velocity.

Again, since the power is expressed by the equation $u = (p \ a) \ v$, and since $p \ a$, or the total pressure, varies as v^2 , the work varies as v^3 . From this it follows that, if the velocity is multiplied by 2, and, consequently, the total pressure by 4, the work performed $(p \ a) \ v$ will be multiplied by $2^a = 8$. We thus team that the power applied varies as the cube of the velocity.

MEASUREMENT OF VENTILATING CURRENTS.

The measurement and calculation of any circulation in a mine airway includes the measurement of (a) the velocity of the air-current, (b) of pressure, (c) of temperature, (d) calculation of pressure, quantity, and horse-power of the circulation.

These measurements should be made at a point in the airway where the airway has a uniform section for some distance, and not far from the foot of

the downcast shaft or the fan drift.

Measurement of Velocity.—For the purpose of mine inspection, the velocity of the air-current should be measured at the foot of the downcast, at the mouth of each split of the air-current, and at each inside breakthrough, in each split. These measurements are necessary in order to show that all the

air designed for each split passes around the face of the workings.

The measurement of the velocity of a current is best made by means of the anemometer. This instrument consists of a vane placed in a circular frame and having its blades so inclined to the direction of its motion that 1 ft. of lineal velocity in the passing air-current will produce 1 revolution of the vane. These revolutions are recorded by means of several pointers, each having a separate dial upon the face of the instrument, the motion being communicated by a series of gear-wheels arranged decimally to each other. Most anemometers are provided with a large central pointer that makes I revolution for each 100 revolutions of the vane. The dial for this pointer is marked by 100 divisions, which record the number of lineal feet of velocity. In very accurate work with the anemometer, certain constants are used as suggested by the instrument maker, but these constants are of little value in ordinary practice and are of doubtful value even in more accurate observations.

The measurement of the velocity of an air-current must necessarily represent only approximately the true velocity in the airway. The air travels with a greater velocity in the center of the airway, and is retarded at

the sides, top, and bottom by the friction of these surfaces. Hence, the air to a large extent rolls upon these surfaces, which naturally generates an eddy at the sides of airways. When measuring the air, the amemometer should be held in a position exactly perpendicular to the direction of the current, and moved to occupy different positions in the airway, being held an equal time in each position, or it may be moved continuously around the margin of the airway, and through the central portion. The person taking the observation should observe the caution of not obstructing the area of the airway by his body, as the area is thereby reduced, and the velocity of the current increased. The area of the airway is accurately measured at the point where the observations are taken (see Calculation of Quantity).

To obtain the quantity of air passing (cubic feet per minute), multiply the area of the airway, at the point where the velocity is measured, by the

velocity.

EXAMPLE.—The anemometer gives a reading of 1,320 ft. in 2 minutes, the height of the airway is 6 ft. 6 in., and its average width 8 ft. 8 in. What volume of air is passing in the airway per minute?

$$6\frac{1}{4} \times 8\frac{1}{4} \times \frac{1,320}{2} = 37,180$$
 cu. ft. per min.

The measurement of the ventilating pressure is made by means of a water column in the form of a water gauge.

Water Gauge.—The water gauge is simply a glass U tube open at both ends. Water is placed in the bent portion of the tube, and stands at the same height in both arms of the tube when each end of the tube is subjected to the same pressure. If,



greater pressure than the other end, the water will be forced down in that arm of the tube, and will rise a corresponding height in the other arm, the difference of level in the two arms of the tube representing the water column balanced by the excess of pressure to which the water in the first arm is subjected. An adjustable scale graduated in inches measures the height of the water column. The zero of the scale is adjusted to the lower water level, and the upper water level will

however, one end of the tube is subjected to a



FIG. 6.

then give the reading of the water gauge. One end of the glass tube is drawn to a narrow opening to exclude dust, while the other end is bent to a right angle, and passing back through the standard to which the tube is attached, is cemented into the brass tube that passes through a hole in the partition or brattice, when the water gauge is in use. The bend of the tube is contracted to reduce the tendency to oscillation in the height of water column. (See Fig. 5.)

When in use, the water gauge must be in a perpendicular position. It is placed upon a brattice occupying a position between two airways, as shown at A. Fig. 6. The brass tube forming one end of the water gauge is inserted in a cork, and passes through a hole bored in the brattice. The water gauge must not be subjected to the direct force of the air-current, as in this case the true pressure will not be given. Fig. 6 shows the instrument as occupying a position in the breakthrough, between two entries. It will be observed that the water gauge records a difference of pressure, each end of the water gauge being subject to atmospheric pressure, but one end in addition being subject to the ventilating pressure, which is the difference of

pressure between the two entries. The water gauge thus enables us a measure the resistance of the mine intoge from its position between the airways. If placed in the first breakthrough, at the foot of the shaft, measures the entire resistance of the mine, but if placed at the mouth of split, it measures only the resistance of that split. It never measures the control of the shaft, measures the control of the shaft, and the split is the same of the shaft of resistance outbye from its position in the mine, but always inbye (see Calculation of Programs) tion of Pressure).

Measurement of Temperature.—It is important to measure the temperature of the air-current at the point where the velocity is measured, as the temperature is an important factor of the volume of air passing (see Expansion)

sion of Air and Gases, etc.).

Thermometers.—Thermometers measure changes in the temperature of the atmosphere by the contraction and expansion of mercury or spirits; or the may be made entirely of metal, and the changes of temperature are the measured by the expansion and contraction of the sensitive metallic portion. These latter are known as aneroid thermometers. The Fahren heit thermometer is the one most commonly used in America. By this scale, the freezing point of water at the sea level is placed at 32° above zero the boiling point of water at sea level is placed at 212° above zero, so that the space between these two points is divided into 180°.

Réaumur and Centigrade thermometers are used on the continent of Europe. Of these two, the first is generally used in Germany, and the second in France, but the latter is almost exclusively used by the scientists

of all nations.

In the Réaumur thermometer, the freezing and boiling points are placed at 0° and 80°, respectively. In the Centigrade, the freezing and boiling points are placed at 0° and 100°, respectively.

To Convert Fahrenheit into Centigrade.—(1) Subtract 32 and divide the remainder by 1.8, or multiply by §

If a Fahrenheit thermometer registers 167°, what will be the register by a

Centigrade thermometer?

 $\frac{167-32}{1.8} = 75^{\circ}$ Centigrade. $\frac{(167-32)5}{9} = 75^{\circ}$ Centigrade.

To Convert Centigrade Into Fahrenheit.—(1) Multiply by 1.8, or 3, and add 32. If the Centigrade thermometer registers 75°, what will be the register by a Fahrenheit thermometer?

$$75 \times 1.8 + 32 = 167^{\circ}$$
 Fahrenheit. $\frac{75 \times 9}{5} + 32 = 167^{\circ}$ Fahrenheit.

To Convert Fahrenheit Into Réaumur.—(1) Subtract 32, and divide by 2.25, or multiply by \$.

If the Fahrenheit thermometer registers 113°, what will be the register by

the Réaumur thermometer?

$$\frac{113-32}{2.25} = 36^{\circ}$$
 Réaumur. $\frac{(113-32)4}{9} = 36^{\circ}$ Réaumur.

To Convert Réaumur Into Fahrenheit.—(1) Multiply by 2.25, or multiply by 3. and add 32.

If the Réaumur thermometer registers 36°, what will be the register by the Fahrenheit thermometer?

$$36 \times 2.25 + 32 = 113^{\circ}$$
 Fahrenheit. $\frac{36 \times 9}{4} + 32 = 113^{\circ}$ Fahrenheit.

To Convert Reaumur into Centigrade.—Multiply by 1.25.

If a Réaumur thermometer registers 32°, what will be the register by a Centigrade thermometer?

 $32 \times 1.25 = 40^{\circ}$ Centigrade. To Convert Centigrade Into Réaumur.—Multiply by .8.

If a Centigrade thermometer registers 40°, what will be the register by a Réaumur thermometer?

 $40 \times .8 = 32^{\circ}$ Réaumur.

Calculation of Mine Resistance.—The mine resistance is equal to the total pressure p a that it causes. This mine resistance is dependent upon three factors: (a) The resistance k offered by 1 sq. ft. of rubbing surface to a current having a velocity of 1 ft. per minute. The coefficient of friction k, or the unit of resistance, is the resistance offered by the unit of rubbing surface to a current of a unit velocity. This unit resistance has been variously estimated by different authorities (see following table). The value most universally accepted, however, is that known as the Atkinson coefficient

Pressure per

(.000000217). (b) The mine resistance, which varies as the square of the velocity. (c) The rubbing surface. Hence, if we multiply the unit resistance by the square of the velocity, and by the rubbing surface, we will obtain the total mine resistance as expressed by the formula $pa = ksv^t$.

TABLE OF VARIOUS COEFFICIENTS OF FRICTION OF AIR IN MINES.

	Sq. Ft. Decimals of a Pound.
J. J. Atkinson's treatise	.0000000217
A. Devillez in Ventilation des Mines:	
Forchies	.000000008211
Crachet-Picquery	.000000008928
Grand Baisson	.000000008611
Average of 2, 3, and 4	.000000008585
Used in Ventilation des Mines	.000000009511
Arched Tunnels	.000000002113
Along a working face of coal	.000000014266
G. G. Andre, Atmosphere of Coal Mines	
Peclet, Cheminee (Devillez, p. 112)	.000000003697
D. K. Clark	.000000002272
According to Goupilliere's Cours d' Exploitation des Mines, Vol. II. p. 389:	.0000000022.2
D'Aubuisson	.000000001955
Navier	.000000001872
W. Fairley	.00000001
J. Stanley James	.00000000929

It will be observed that J. J. Atkinson's coefficient is greatly in excess of any other, with the exception of Andre's. Fairley's is derived from an average taken between Atkinson, Devillez, and Clark, and, undoubtedly, it is an exceedingly simple coefficient to work out calculations with, as it will save a great mass of figures. James, in his work on colliery ventilation, reduces the coefficient still further on the authority of the Belgian Mine Commission, but he gives a most unwieldy figure to use.

Atkinson's figure is the one most in use, and if it is too high, it errs on the

side of safety, and it is always advisable to have plenty of spare ventilating power at a mine. For this reason, and until a regular and thorough investigation, made by a commission of competent men, provides a standard coefficient, we prefer to abide by Atkinson's coefficient, and it is used in all our

Calculation of Power, or Units of Work per Minuts.—If we multiply the total pressure by the velocity (feet per minute) with which it moves, we obtain the units of work per minute, or the power upon the air. Hence, u = pav =ks v3, which is the fundamental expression for work per minute, or power.

The Equivalent Orifica.—This term, often used in regard to ventilation, evaluates the mine resistance, or, as will be seen from the equation given below for its value, it expresses the ratio that exists between the quantity of air passing in an airway and the pressure or water gauge that is produced by the circulation. This term was suggested by M. Daniel Murgue, and refers to the flow of a fluid through an orifice in a thin plate, under a given The formula expressing the velocity of flow through such an orifice is $v = \sqrt{2gh}$; multiplying both members of this equation by A, and substituting for the first member A v, its value q, we have, after transposing and

, in which .62 is the coefficient for correcting for vena contracta. A = $.62\sqrt{2gh}$

the vena contracta of the flow. Reducing this to cubic feet per minute and inches of water gauge represented by i, we have, finally, the equation $A = .0004 \times \frac{q}{1000}$. By this formula, Murgue has suggested assimilating the

flow of air through a mine to the flow of a fluid through a thin plate; since, in each case, the quantity and the head or pressure vary in the same ratio. Thus, applying this formula to a mine, Murgue multiplies the ratio of the quantity of air passing (cubic feet per minute) and the square root of the water gauge (inches) by .0004, and obtains an area A, which he calls the equivalent orifice of the mine.

Potential Factor of a Mine. (Proposed by J. T. Reard.)—Equations 8 and 27.

pages 370-371, give, respectively, the pressure and the power that will circulate a given quantity of air per minute in a given airway. These equation may be written as equal ratios, expressed in factors of the current and the airway, respectively; thus, $\frac{p}{q^2} = \frac{ks}{a^3}$, and $\frac{u}{q^3} = \frac{ks}{a^3}$, which show that the ratio between the pressure and the square of the quantity it circulates in any given airway is equal to the ratio between the power and the cube of the quantity it circulates. Solving each of these equations with respect to q^i we have the following:

With respect to pressure,

$$q = \left(a\sqrt{\frac{a}{k s}}\right)\sqrt{p}.$$

With respect to power,

$$q = \left(\frac{a}{\sqrt[3]{k s}}\right) \sqrt[3]{u}.$$

Hence, we observe that, in any airway, for a constant pressure, the quantity of air in circulation is proportional to the expression $a\sqrt{\frac{a}{ks}}$; and, for a constant power, the quantity is proportional to the expression $\frac{a}{\sqrt[3]{ks}}$, which terms are called the potentials of the mine with respect to pressure and power, respectively; and their values $\frac{q}{\sqrt[3]{p}}$ and $\frac{q}{\sqrt[3]{p}}$ are the potentials of the

current with respect to pressure and power, respectively. These factors, it will be observed, evaluate the airway, as they determine the quantity of air a given pressure or power will circulate in that airway (cubic feet per minute). By their use, the relative quantities of air any given pressure or power will circulate in different airways are readily determined. The rule may be stated as follows:

Rule.—For any given pressure or power, the quantity of air in circulation is always proportional to the potential for pressure, or the potential for power, as

the case may be.

This rule finds important application in splitting (see Calculation of Natural Splitting). In all cases where the potential is used as a ratio, the relative potential may be employed by omitting the factor k; or it may be employed to obtain the pressure and power, in several splits by multiplying the final result by k (see Formulas 46, 47, etc., page 378).

the final result by k (see Formulas 46, 47, etc., page 378). EXAMPLE.— 20,000 cu. ft. of air is passing in a mine in which the airway is 6 ft. \times 8 ft., and 10,000 ft. long, under a certain pressure; it is required to find what quantity of air this same pressure will circulate in a mine in which

the airway is 6 ft. \times 12 ft., and 8,000 ft. long.

Calculating the potential X_p with respect to the pressure for each of these mines, or airways, we have, using the relative potential,

$$X_1 = 6 \times 8\sqrt{\frac{6 \times 8}{2(6+8) \times 10.000}} = .62845$$
, and $X_2 = 6 \times 12\sqrt{\frac{6 \times 12}{2(6+12) \times 8.000}} = 1.1384$. Since the ratio of the quantities is equal to the ratio of the potentials with respect to pressure, in these two mines, we write the proportion 20.000 $\times 1.1384 = 36.229$ cm. ft. per

tion 20,000: q_2 :: .62845: 1.1384, and $q_2 = \frac{20,000 \times 1.1384}{.62845} = 36,229$ cu. ft. per min.

EXAMPLE.— 20,000 cu. ft. of air is passing in a mine in which the airway is 6 ft. \times 8 ft. and 10,000 ft. long, under a certain power; it is required to find what quantity of air will be circulated by this same power in a mine in which the airway is 6 ft. \times 12 ft., and 8,000 ft. long.

We calculate the potential $X_{\mathbf{w}}$ with respect to power for each of these

mines, using, as before, the relative potential. Thus, $X_1 = \frac{6 \times 8}{\sqrt[3]{2(6+8) \times 10,000}}$ 7337, and $X_2 = \frac{6 \times 12}{\sqrt[3]{2(6+12) \times 8,000}} = 1.0905$. Then, in this case, since the

ratio of the quantities is equal to the ratio of the potentials with

respect to power, we write the proportion, $20.000: q_0:: .7337: 1.0905$, and $20,000 \times 1.0905$ = 29.726 cu. ft. per min. .7337

The following table will serve to illustrate the use of the formulas employed in these calculations. It will be observed that there are several formulas for quantity, and for velocity, and for work or horse-power, but in each respective case the several formulas are derived by simple transposition of the terms of the original formula, and are tabulated here for convenience. Choice must be made in the use of any of these formulas, according to the known terms in each example. Thus, an example may ask: What pressure will be produced in passing a given quantity of air through a certain mine, the size and length of the airways being given? k 8 q2 We then use the formula p =But if the question asks what quantity of air a given pressure will produce in this same mine, we use the $\frac{p a}{k s}$ formula q = 1×α. It will be observed that this second formula is a

simple transposition of the first. In like manner the question may be asked, what power will produce a certain quantity of air in a certain airway; and the expression used, in this -. Or, the question may be asked, what quantity of air will be produced in a given airway by means of a certain power or work applied u to the airway. In this case, the formula used is q =If the question asks for the power required to produce a given velocity in a given airway, the formula employed is $u = k s v^3$. All of these formulas are derived k 8 v4 by combining the simple formulas p =-, q = a v, and u = q p.

To illustrate the use of the formulas, we take as an example an underground road, 5 ft. wide by 4 ft. high, and 2,000 ft. in length, and calculate the value of each symbol or letter, assuming a velocity of 500 ft. per minute.

•	Symbol.	Value of Symbol for this Particular Example.
Area of airway (5 ft. × 4 ft.)	a	20 sq. ft.
Horsepower *	h	2.959 H. P.
Horsepower *	h k l	.0000000217 lb.
Length of airway	ī	2.000 ft.
Length of airway Perimeter of airway, 2(5 ft. + 4 ft.)	0	18 ft.
Pressure (lb. per sq. ft.)	n	9.765 lb.
Quantity of air (cu. ft. per min.)	$egin{pmatrix} p \\ q \\ s \end{bmatrix}$	10,000 cu. ft.
Area of rubbing surface	8	36,000 sq. ft.
Units of work per minute (power)	24	97,650 ftlb.
Velocity (ft. per min.)	v i A X X p	500 ft.
Water genoe	i	1.87788 in.
Equivalent orifice of the mine	À	2.919 sq. ft.
Potential for power	X	217.16 units.
Potential for pressure	X.	3.200 units.
Weight of 1 cu. ft. of downcast air	10	.08098 1b.
Motive column (downcast air)		120.5 ft.
Depth of furnace shaft		306.77 ft.
Average temperature of the upcast column	Ť	350° F.
Average temperature of the downcast column	î	32° F

^{*}A horsepower is equal to 33,000 units of work.
†This coefficient of friction is an invariable quantity, and is the same in every calculation relating to the friction of air in mines.

Note.—The water gauge is calculated to five decimal places to enable all the other values to be accurately arrived at. In practice, it is only read to one decimal place.

FORMULAS.

On the right side of each formula, the various calculations, based on the example given, are worked out in figures.

To Find:	No.	Formula.	Specimen Calculation.
Rubbing sur- face of an air- way. (Sq. ft.)	1	s == lo	$2,000 \times 18 = 36,000 \text{ sq. ft.}$
Area of an airway. (Sq.ft.)	2	$a=rac{q}{v}$	$\frac{10,000}{500} = 20 \text{ sq. ft. of area.}$
Velocity. (Ft. per min.)	3	$v=rac{q}{a}$	$\frac{10,000}{20} = 500 \text{ ft.}$
	4	$v = \sqrt[3]{\frac{u}{k s}} .$	$\sqrt[3]{\frac{97,650}{.0000000217 \times 36,000}} = 500 \text{ ft.}$
	5	$v = \sqrt{\frac{p a}{k s}}$	$\sqrt{\frac{9.765 \times 20}{.0000000217 \times 36,000}} = 500 \text{ ft.}$
	6	$v = \frac{u}{p a}$	$\frac{97,650}{9.765 \times 20} = 500 \text{ ft.}$
Pressure. (Lb. per sq. ft.)	7	$p = \frac{k s r^2}{a}$	$\frac{.0000000217 \times 36,000 \times 500^2}{20} = 9.765 \text{ l}$
	8	$p = \frac{k s q^2}{a^3}$	$ \frac{.0000000217 \times 36,000 \times 10.000^{4}}{20^{3}} = 9.765 \text{ lb.} $
	9	$p = \frac{u}{q}$	$\frac{97,650}{10,000} = 9.765 \text{ lb.}$
	10	p = M w	$120.58 \times .08098 = 9.765 \text{ lb.}$
	11	$p=5.2\;i$	$5.2 \times 1.87788 = 9.765 \text{ lb.}$
	12	$p = \frac{q^2}{X_u^3}$	$\frac{10,000^2}{217.16^3} = 9.765 \text{ lb},$
	13	$p = \frac{q^2}{X_p^2}$	$\left(\frac{10,000}{3,200}\right)^2 = 9.765 \text{ lb.}$
Water gauge. (Inches.)	14	$i=rac{p}{5.2}$	$\frac{9.765}{5.2} = 1.87788 \text{ in.}$
Resistance of an airway.	15	$p a = k s v^2$	$.0000000217 \times 36,000 \times 500^{9} = 195.3 \text{lb}$
(Total pressure, lb.)	16	$p a = \frac{u}{v}$	$\frac{97,650}{500} = 195.3 \text{ lb.}$

To Find:	No.	Formula.	Specimen Calculation.
Quantity.	17	q = a v	$20 \times 500 = 10,000$ cu. ft.
Cu.ft.per min)	18	$q=rac{u}{p}$	97,650 9.765 = 10,000 cu. ft.
	19	$q = \sqrt{\frac{p a}{k s}} \times a$	$ \sqrt{\begin{array}{c} 9.765 \times 20 \\ 0.000000217 \times 36,000 \times 20 \\ = 10,000 \text{ cu. ft.} \end{array}} $
	20	$q = \sqrt[3]{\frac{u}{k\bar{s}}} \times a$	
	21	$q = X_u t^2 \overline{u}$	$217.16 \times t^{3/97,650} = 10,000$ cu. ft.
	22	$q = \sqrt[3]{X_{p^2} u}$	$1^{3/3}, 200^{2} \times 97,650 = 10,000 \text{ cu. ft.}$
	23	$q = X_p \sqrt{p}$	$3,200 \times \sqrt{9.765} = 10,000 \text{ cu. ft.}$
Units of work	24	u = a r p	$20 \times 500 \times 9.765 = 97,650 \text{ ftlb.}$
per minute, or power on the	25	u = q p	$10,000 \times 9.765 = 97,650 \text{ ftlb.}$
air. (Ftlb.permin)	26	$u = k s v^3$.0000000217 \times 36,000 \times 500 ³ = 97,650 ftlb.
	27	$u = \frac{k s q^3}{a}$	$0000000217 \times 36,000 \times 10,000^{3}$ $= 97,650 \text{ ftlb.}$
	28	u = h33,000	$2.959 \times 33,000 = 97,650 \text{ ftlb.}$
	29	$u = \frac{q^3}{X_u^3}$	$\frac{10,000^3}{217.16^3} = 97,650 \text{ ftlb.}$
	30	$u=rac{q^3}{X_p^2}$	$\frac{10,000^3}{3,200^2} = 97,650 \text{ ftlb.}$
Horsepower.	31	$h = \frac{i}{33,000}$	$\frac{97,650}{33,000} = 2.959 \text{ H. P.}$
Power poten- tial. (Units.)	32	$X_{u} = \frac{a}{1^{3} k s}$	$\frac{20}{13^{3} \cdot 0000000217 \times 36,000} = 217.16 \text{ units}$
	33	$X_u = \sqrt[3]{\frac{q^2}{p}}$	$\sqrt[3]{\frac{10,000^2}{9.765}} = 217.16 \text{ units.}$
	34	$X_u = \frac{q}{\prod_{i=1}^{n} u}$	$\frac{10,000}{1^{3/97,650}} = 217.16 \text{ units.}$

To Find:	No.	Formula.	Specimen Calculation.
Pressure potential. (Units.)	35	$X_p = a\sqrt{\frac{a}{k s}}$	$ \begin{array}{c} 20 \sqrt{\frac{20}{.000000217 \times 36,000}} \\ = 3,200 \text{ units.} \end{array} $
	36	$X_p = \frac{q}{V p}$	$\frac{10,000}{V 9.765} = 3,200 \text{ units.}$
Equivalent orifice. (Sq. ft.)	37	$A = \frac{.0004q}{\sqrt{i}}$	$\frac{.0004 \times 10,000}{\sqrt{1.87788}} = 2.919 \text{ sq. ft.}$
Motivecolumn, downcast air. (Feet.)	38	$M = D \times \frac{T - t}{459 + T}$	$306.77 \times \frac{350 - 32}{459 + 350} = 120.5 \text{ ft.}$
	39	$M = \frac{p}{w}$	$\frac{9.765}{.08098} = 120.5 \text{ ft.}$
Motivecolumn, upcast air. (Feet.)	40	$M = D \times \frac{T-t}{459+t}$	$306.77 \times \frac{350 - 32}{459 + 32} = 198.7 \text{ ft.}$
(=====,	39	$M = \frac{p}{w}$	$\frac{9.765}{.04915} = 198.7 \text{ ft.}$

Variation of the Elements.—In the illustration of the foregoing table, we have assumed fixed conditions of motive column, as well as fixed conditions in the mine airways. It is often convenient, however, to know how the different elements, as velocity v, quantity q, pressure p, power u, etc., will vary in different circulations; since we may, by this means, compare the circulations in different airways, or the results obtained by applying different pressures and powers to the same airway. These laws of variation must always be applied with great care. For example, before we can ascertain how the quantity in circulation will vary in different airways, we must know whether the pressure or the power is constant or the same for each airway. The following rules may always be applied:

For a constant pressure: v varies as $\sqrt{\frac{a}{lo}}$; q varies as $a\sqrt{\frac{a}{lo}}$ (relative potential for pressure).

For a constant power: v varies as $\frac{1}{t^2 lo}$; q varies as $\frac{a}{t^2 lo}$ (relative potential for power).

For a constant velocity: q varies as a; p varies as $\frac{lo}{a}$; u varies as lo.

For a constant quantity: v varies inversely as a; p varies inversely as X_*^2 (potential for power); u varies inversely as X_u^3 (potential for power) or directly as p.

For the same sirway: The following terms vary as each other: $v, q, \sqrt{p}, \sqrt[3]{u}$.

SIMILAR AIRWAYS.

r =length of similar side, or similar dimension.

For a constant pressure: v varies as $\sqrt{\frac{r}{l}}$; q varies as $r^2 \times \sqrt{\frac{r}{l}}$; r varies as $r^2 \times \sqrt{\frac{r}{l}}$; r varies as

For a constant power: v varies as $\frac{1}{t^2/\overline{t}r}$; q varies as $r imes \sqrt[3]{\frac{r^2}{t}}$; r varies as $\frac{1}{l q^3}$, or $\sqrt[4]{l q^3}$.

For a constant velocity: q varies as r^2 ; p varies as $\frac{l}{r}$; u varies as lr; r varies as \sqrt{q} , $\frac{l}{p}$, or $\frac{u}{l}$.

For a constant quantity: v varies inversely as re; p and u vary inversely as $\frac{\tau^5}{l}$; r varies as $\frac{1}{\sqrt{v}}$, $\sqrt[5]{\frac{l}{p}}$, or $\sqrt[5]{\frac{l}{u}}$.

FURNACE VENTILATION.

p (motive column) varies as D; q varies as \sqrt{D} . FAN VENTILATION.

It has been customary in calculations pertaining to the yield of centrifugal ventilators to assume as follows: q varies as n; p varies as n²; u varies as n3.

More recent investigation, however, shows that when we double the speed we do not obtain double the quantity of air in circulation; or, in other words, the quantity does not vary exactly as the number of revolutions of words, the quantity does not vary exactly as the number or revolutions of the fan. Investigation also points to the fact that the efficiency of centrifugal ventilators decreases as the speed increases. To what extent this is the case has not been thoroughly established. The variation between the speed of a fan and the quantity, pressure, power, and efficiency, as calculated from a large number of reliable fan tests, may be stated as follows:

For the same fan, discharging against a constant potential: q varies as n^{-10} .

The efficiency here referred to is the mechanical efficiency, or the ratio between the affective work q and the theoretical work of the fan.

between the effective work ap and the theoretical work of the fan.

DISTRIBUTION OF AIR IN MINE VENTILATION.

When a mine is first opened, the air is conducted in a single current around the face of all the headings and workings, and returns again to the upcast shaft, where it is discharged into the atmosphere. As the development of the mine advances, however, it becomes necessary to divide the air into two or more splits or currents. This division or splitting of the aircurrent is usually accomplished at the foot of the downcast, or as soon as possible after the current enters the mine. There are several reasons why the air-current should be thus divided. The most important reason is that the mine is thereby divided into separate districts, each of which has its own ventilating current, which may be increased or decreased at will. Fresh air is thus obtained at the face of the workings, and the ventilation is under more perfect control. It often happens that certain portions of a mine are more gaseous than others, and it is necessary to increase the volume of air in these portions, which can be readily accomplished when each district heas its own separate circulation. Again, the cases and foul sire not has its own separate circulation. Again, the gases and foul air are not conducted from one district to another, but each district is supplied with fresh air direct from the main intake. Should an explosion occur in any part of the mine, it is more apt to be confined to one locality when a mine is thus divided into separate districts. Another consideration is the reduced power necessary to accomplish the same circulation in the mine; or the increased circulation obtained by the use of the same power.

Requirements of Law in Regard to Splitting.—The Anthracite Mine Law of Pennsylvania specifies that every mine employing more than 75 persons must be divided into two or more ventilating districts, thus limiting the number that are allowed to work on one air-current to 75 persons. The Bituminous Mine Law of Pennsylvania limits the number allowed to work upon one current to 65 persons, except in special cases, where this number may be increased to 100 persons at the discretion of the mine inspector.

Practical Splitting of the Air-Current. - When the air-current is divided into two or more branches, it is said to be split. The current may be divided one or more times; when split or divided once, the current is said to be traveling

in two splits, each branch being termed a split. The number of splits in which a current is made to travel is understood as the number of separate currents in the mine, and not as the number of divisions of the current.

Primary Splits.—When the main air-current is divided into two or more

splits, each of these is called a primary split.

splits, each of these is called a primary split.

Secondary Splits.—Secondary splits are the divisions of a primary split.

Tertiary Splits.—Tertiary splits result from the division of a secondary split.

Equal Splits of Air.—When a mine is spoken of as having two or more equal splits, it is understood to mean that the length and the size of the separate airways forming those splits are equal in each case. It follows, of course, from this that the ventilating current traveling in each split will be the same, inasmuch as they are all subject to the same ventilating pressure. When an equal circulation is obtained in two or more splits by the use of regulators, these splits cannot be spoken of as equal splits.

Unequal Splits of Air.—By this is meant that the airways forming the splits are of unequal size or length. Under this head we will consider (a) Natural Division of the Air-Current; (b) Proportionate Division of the Air-Current as results from is meant any division of the air that is accomplished without the use of regulators; or, in other words, such division of the air-current as results from natural means.

other words, such division of the air-current as results from natural means. If the main air-current at any given point in a mine is free to traverse two separate airways in passing to the foot of the upcast shaft, and each of these airways is free or an open split, i. e., contains no regulator, the division of the air will be a natural division. In such a case, the larger quantity of air will always traverse the shorter split of airway. In other words, an air-current always seeks the shortest way out of a mine. A comparatively small

current, however, will always traverse the long split or airway.

Calculation of Natural Splitting.—It is always assumed, in the calculation of the splitting of air-currents, that the pressure at the mouth of each split, starting from any given point, is the same. Since this is the case, in order to find the quantity of air passing in each of several splits starting from a common point, the rule given under Potential Factor of a Mine is applied.

This rule may be stated as follows:

The ratio between the quantity of air passing in any split and the pressure potential of that split is the same for all splits starting from a common point. Also, the ratio between the entire quantity of air in circulation in the several splits and the sum of the pressure potentials of those splits is the same as the above ratio, and is equal to the square root of the pressure.

Expressed as a formula, indicating the sum of the pressure potentials

Expressed as a londing, indicating
$$\Sigma X_p$$
, this rule is $\frac{Q}{\Sigma X_p} = \frac{q_1}{q_1} = \sqrt{p}$. Hence, $p = \frac{Q^2}{(\Sigma X_p)^2}$ and $u = \frac{Q^3}{(\Sigma X_p)^2}$ express the pressure and power, respectively, absorbed by the circulation of the splits. These are the basal formulas for splitting, from which any of the factors may be calculated by transposition. They will be found illustrated in the table at the end of this

section. We will give here two examples only, showing the calculation of the natural division of an air-current between several splits. We have, from

the above formulas, $q_1 = \frac{1}{\sum X_p} Q$.

EXAMPLE.—In a certain mine, an air-current of 60,000 cu. ft. per minute is traveling in two splits as follows: Split A, 6 ft. \times 8 ft., 5,000 ft. long; split B, 5 ft. \times 8 ft., 10,000 ft. long. It is required to find the natural division of this air-current.

Calculating the relative potentials for pressure in each split, we have

for split A,
$$X_1 = 48\sqrt{\frac{48}{2(6+8)5,000}} = .9888$$

for split B, $X_2 = 40\sqrt{\frac{40}{2(5+8)10,000}} = .4961$ and $\Sigma X_p = 1.3849$;

and substituting these values, we have,

$$q_1 = \frac{.888}{1.3849} \times 60,000 = 38,506 \text{ cu. ft. per min.};$$

 $q_2 = \frac{.4961}{1.3849} \times 60,000 = 21,494 \text{ cu. ft. per min.}$

and

EXAMPLE.—In a certain mine, there is an air-current of 100,000 cu. ft. per minute traveling in three splits as follows: Split A, 6 ft. \times 10 ft., 8,000 ft. long; split B, 6 ft. \times 12 ft., 15,000 ft. long; split C, 5 ft. \times 10 ft., 6,000 ft. long. Find the natural division of this current of air.

Calculating the respective relative potentials with respect to pressure,

we have

for split A,
$$X_1 = 60\sqrt{\frac{60}{2(6+10)\times 8,000}} = .9185;$$

for split B, $X_2 = 72\sqrt{\frac{72}{2(6+12)\times 15,000}} = .8314;$
for split C, $X_3 = 50\sqrt{\frac{50}{2(5+10)\times 6,000}} = .8333.$

Adding these potentials, we have $\Sigma X_{p} = .9185 + .8314 + .8333 = 2.5832$. Then, applying the foregoing rule, we have

$$q_1 = \frac{.9185}{2.5832} \times 100,000 = 35,556 \text{ cu. ft. per min.;}$$
 $q_2 = \frac{.8314}{2.5832} \times 100,000 = 32,184 \text{ cu. ft. per min.;}$
 $q_3 = \frac{.8333}{2.5832} \times 100,000 = 32,260 \text{ cu. ft. per min.}$

and

Proportional Division of the Air-Current.—It continually happens that different proportions of air are required in the several splits of a mine than would be obtained by the natural division of the air-current. It is usually the case that the longer splits employ a larger number of men, and require a larger quantity of air passing through them. They, moreover, liberate a larger quantity of mine gases, for which they require a larger quantity of air than is passing in the smaller splits. The natural division of the air-current would give to these longer splits less air, and to the shorter ones a larger amount of air, which is directly the reverse of what is needed. On this account, recourse must be had to some means of dividing this air portionately, as required. This is accomplished by the use of regulators, of which there are two general types, the box regulator and the door regulator.

Box Regulator.—This is simply an obstruction placed in those airways that would naturally take more air than the amount required. It consists of a brattice or door placed in the entry, and having a small shutter that can be opened to a greater or less amount. The shutter is so arranged as to allow the passage of more or less air, according to the requirements. The box regulator is, as a rule, placed at the end or near the end of the return airway of a split. It is usually placed at this point as a matter of convenience, Proportional Division of the Air-Current.—It continually happens that differ-

way of a split. It is usually placed at this point as a matter of convenience, because, in this position, it obstructs the roads to a less extent, the haulage way of a spint. It is usually placed at this point as a matter of convenience, because, in this position, it obstructs the roads to a less extent, the haulage from the back entry in this split being carried over to the main haulway, through a cross-cut, before this point is reached. The difficulty, however, can be avoided, in most cases, by proper consideration in the planning of the mine with respect to haulage and ventilation. The objection to this form of regulator is that, in effect, it lengthens the airway, or increases its resistance, making the resistance of all the airways, per foot of area, the same. It is readily observed that, by thus increasing the resistance of the mine, the horsepower of the ventilation is largely increased, for the same circulation. This is an important point, as it will be found that the power required for ventilation is thus increased anywhere from 50% to 100% over the power required when the other form of regulator can be adopted.

Door Regulator.—In this form of regulator, which was first introduced by Beard, the division of the air is made at the mouth of the split. The regulator consists of a door hung from a point of the rib between two entries, and swung into the current so as to cut the air like a knife. The door is provided with a set lock, so that it may be secured in any position, to give more or less air to the one or the other of the splits, as required. The position of this regulator door, as well as the position of the shutter in the box regulator, is always ascertained practically by trial. The door is set so as to divide the area of the airway proportionate to the work absorbed in the

The pressure in any split is not increased, each spli respective splits.

retaining its natural pressure.

Calculation of Pressure for Box Regulators.—When any required division the air-current is to be obtained by the use of box regulators, these placed in all the splits, save one. This split is called the open, or free, split. and its pressure is calculated in the usual way by the formula p =The natural pressure in this open split determines the pressure of the entire

mine, since all the splits are subject to the same pressure in this form of splitting First, determine in which splits regulators will have to be placed, in order to accomplish the required division of the air. Calculate the natural pressure, or pressure due to the circulation of the air-current, for each split,

k8 q2 when passing its required amount of air, using the formula p =split showing the greatest natural pressure is taken as the free split. In each of the other splits, box regulators must be placed, to increase the pressure in those splits; or, in other words, to increase the resistance of those splits

per unit of area

EXAMPLE.—The ventilation required in a certain mine is: split A, 6 ft. × 9 ft., 8,000 ft. long; 40,000 cu. ft. per min.
split B, 5 ft. × 8 ft., 6,000 ft. long; 40,000 cu. ft. per min.
split B, 5 ft. × 8 ft., 8,000 ft. long; 40,000 cu. ft. per min.
split D, 6 ft. × 8 ft., 10,000 ft. long; 30,000 cu. ft. per min.
split D, 6 ft. × 8 ft., 10,000 ft. long; 30,000 cu. ft. per min.
In which of these splits should regulators be placed, to accomplish the required division of sir, and what will be the mine pressure?
Calculating the pressure due to friction in each split, when passing its

Calculating the pressure due to friction in each split when passing its required amount of air, we find,

 $.0000000217 \times 2(6+9)8,000 \times 40,000^{2}$ = 52.92 lb. per sq. ft.; for split A, p = $.0000000217 \times 2(5 + 8)6,000 \times 40,000^{2}$ for split B, p == 84.63 lb. per sq. ft.; 403 = 1.176 lb. per sq. ft.;

Split B has the greatest pressure, and is therefore the free split. Box regulators are placed in each of the other splits to increase their respective pressures to the pressure of the free split or the mine pressure.

the mine pressure in this circulation is 84.63 lb. per sq. ft.

The Size of opening in a box regulator is calculated by the formula for determining the flow of air through an orifice in a thin plate under a certain head or pressure. The difference in pressure between the two sides of a box regulator is the pressure establishing the flow through the opening, which corresponds to the head h in the formula $v = \sqrt{2gh}$. This regulator is usually placed at the end of a split or airway, and since the regulator increases the pressure in the lesser split so as to make it equal to the pressure in the other split, the pressure due to the regulator will be equal to the ventilating pressure at the mouth of the split, less the natural pressure or the pressure due to friction in this split. Hence, when the position of the regulator is at the end of the split, the pressure due to friction in the split is

first calculated by the formula $p=\frac{ksq^2}{a^3}$, and this pressure is deducted from

the ventilating pressure of the free or open split, which gives the pressure due to the regulator. This is then reduced to inches of water gauge, and .0004qsubstituted for i in the formula A =The value of A thus obtained is

the area (square feet) of the opening in the regulator.

EXAMPLE.— 50,000 cu. ft. of air is passing per minute in a certain mine, in two equal splits, under a pressure equal to 2 in. of water gauge, and it is required to reduce the quantity of air passing in one of these splits, by a box regulator placed at the end of the split, so as to pass but 15,000 cu. ft. per

mainute in this split. Find the area of the opening in the regulator, assuming that the ventilating power is decreased to maintain the pressure constant at the mouth of the splits after placing the regulator. The size and length of each split is 6 ft. \times 10 ft. and 10,000 ft. long.

The natural pressure for the split in which the regulator is placed will be

$$p = \frac{k s q^8}{a^3} = \frac{.0000000217 \times 2(6+10) \times 10,000 \times 15,000^8}{(6 \times 10)^3} = 7.233 \text{ lb. per sq. ft.}$$

 $\frac{7.233}{5.2}$ = 1.4 in. of water gauge (nearly), due to friction of the air-

current in this split. And,
$$2-1.4=.6$$
 in. water gauge due to regulator. Finally, $A=\frac{.0004 \, q}{1\sqrt{6}}=\frac{.0004 \times 15,000}{1\sqrt{6}}=7.746 \, \text{sq. ft.}$, area of opening.

Size of Opening for a Door Regulator.—The sectional area at the regulator is divided proportionately to the work to be performed in the respective splits according to the proportion $A_1: A_2:: u_1: u_2$. Or since $A_1 + A_2 = a$, we have $A_1:a::u_1:u_1+u_2$, and $A_1=\frac{u_1}{u_1+u_2}\times a$. This furnishes a method of pro-

portionate splitting in which each split is ventilated under its own natural pressure. The same result would be obtained by the placing of the box regulator at the intake of any split, thereby regulating the amount of air passing into that split, but the door regulator presents less resistance to the flow of the air-current. The practical difference between these two forms of regulators is that in the use of the box regulator each split is wentilated under a pressure equal to the natural pressure of the open or free split, which very largely increases the horsepower required for the ventilation of the mine; while in the use of the door regulator each split is ventilated under its own natural pressure, and the proportionate division of the air is accomplished without any increase of horsepower. This is more clearly explained in the two following paragraphs, and the table showing the comparative horsepowers of the two methods.

Calculation of Horaepower for Box Regulators.—By the use of the box regulator, the pressure in all the splits is made equal to the greatest natural lator, the pressure in all the splits is made equal to the greatest many one. This split is made the open or free split, and its natural pressure becomes the pressure for all the splits, or the mine pressure. This mine pressure, multiplied by the total quantity of air in circulation (the sum of the quantities passing in the several splits), and divided by 33,000, gives the horsebower upon the air, or the horsebower of the circulation. Thus, in the first example given on page 376, in which for split B the pressure p=84.63 lb. per sq. ft. and the total quantity of air passing per minute is 120,000 cu. ft., we have

$$h = \frac{84.63 \times 120,000}{33.000} = 307.745 \text{ H. P.}$$

Calculation of Horsepower for Door Regulators.—In the use of the door regulator, each split is ventilated under its own natural pressure, and, hence, in the calculation of the horsepower of such a circulation, the power of each split must be calculated separately, and the sum of these several powers will be the entire power of the circulation. For the purpose of comparison, we tabulate below the results obtained in the application of these two methods of dividing the air in the above example.

	Natural	Required	Horsepower.	
Splits.		Division.	Door Regulator.	Box Regulator.
Split A , 6 ft. \times 9 ft., 8,000 ft. long Split B , 5 ft. \times 8 ft., 6,000 ft. long Split C , 9 ft. \times 9 ft., 8,000 ft. long Split D , 6 ft. \times 8 ft., 10,000 ft. long	28,277 22,360 47,423 21,940	40,000 40,000 10,000 30,000	64.145 102.582 .356 44.955	102.582 102.582 25.645 76.936
Totals	120,000	120,000	212.038	307.745

SPLITTING FORMULAS.

The following table of formulas will serve to illustrate the methods of calculation in splitting. The example assumes the same airway as that given on page 369 and used to illustrate the table of formulas, page 370, but the aircurrent is divided, as specified in the table:

NATURAL DIVISION.

Primary Splits.—Split (1) = 4 ft. \times 5 ft., 800 ft. long. Split (2) = 4 ft. \times 5 ft., 1,200 ft. long.

To Find:	No.	Formula.	Specimen Calculation.
		$X_p = a\sqrt{rac{a}{ks}} \cdot$	$(1) \ \ 20\sqrt{\frac{20}{.000000217 \times 14,400}} = 5,060$
Potential for pressure.	35	$\Sigma \ X_p = (X_1 + X_2 + ext{etc.}).$	(2) $20\sqrt{\frac{20}{.000000217 \times 21,600}} = 4,131.$ 5,060 + 4,131 = 9,191.
Natural division.	41	$q = \frac{X_p}{\sum X_p} \times Q.$	(1) $\frac{5,060}{9,191} \times 10,000 = 5,505 \text{ cu. ft.}$ (2) $\frac{4,131}{9,191} \times 10,000 = 4,495 \text{ cu. ft.}$

Or the natural division may be calculated from the pressure at the mouth

	23	$q = X_p \sqrt{p}$.	(1) 5,060 $\sqrt{1.1838}$ = 5,505 cu. ft. (2) 4,131 $\sqrt{1.1838}$ = 4,495 cu. ft. See formula (42).
Pressure.	42	$p = \frac{Q^2}{(\Sigma X_p)^2}.$	$\frac{10,000^2}{9,191^2} = 1,1838 \text{ lb.}$
Power.	43	$u = \frac{Q^3}{(\Sigma X_p)^2}.$	$\frac{10,000^3}{9,191^2} = 11,838 \text{ units.}$
Quantity.		$Q = \sum X_p \sqrt{p}.$ $Q = \sqrt[3]{(\sum X_p)^2 u}.$	9,191 $\sqrt{1.1838} = 10,000$ cu. ft. $\sqrt[3]{9,191^2 \times 11,838} = 10,000$ cu. ft.
Increase of quantity due to splitting. (Pressure con- stant.)	46	$Q = \frac{\sum X_p}{X_{p-o}} \times q_o.$	$\frac{9,191}{3,200} \times 10,000 = 28,722 \text{ cu. ft.}$
Increase in quantity due to splitting. (Power con- stant.)	47	$Q = q \sqrt[3]{\left(\frac{\sum X_p}{X_{p-s}}\right)^{\frac{1}{2}}}$	$\sqrt[3]{10,000} \sqrt[3]{\left(\frac{9,191}{3,200}\right)^2} = 20,205 \text{ cu. ft.}$

Secondary Splits.—(1) 4 ft. \times 5 ft., 800 ft. long. (2) 4 ft. \times 5 ft., 500 ft. long. (3) 4 ft. \times 5 ft., 400 ft. long. (4) 4 ft. \times 5 ft., 300 ft. long. The calculation is often shortened, when many splits are concerned, by using the relative polential, omitting the factor k; but the final result must he mu

To Find: No.	No.	Formula	Specimen Calculation.
Relative poten- tial for pressure.	8:	$X_p = a \sqrt{rac{a}{8}}.$	(1) $20\sqrt{\frac{20}{14,400}} = .7471$, (2) $20\sqrt{\frac{20}{9,000}} = .9428$. (3) $20\sqrt{\frac{20}{7,200}} = 1.0541$. (4) $20\sqrt{\frac{20}{5,400}} = 1.2172$.
Natural division.	48	$q_{1} = \frac{q_{1} = Q - q_{2}}{Q}.$ $1 + X_{1}\sqrt{\frac{1}{X_{2}^{2}} + \frac{1}{(X_{3} + X_{4})^{2}}}.$ $q = \frac{X_{p}}{2 X_{p}} \times Q.$	(1) $10,000 - 5,388 = 4,612 \text{ cu. ft.}$ See formula (48). (2) $1 + .7471\sqrt{\frac{1}{9,428}} + \frac{1}{(1.0541 + 1.2172)^2} = 5,388 \text{ cu. ft.}$ (3) $\frac{1}{(1.0541 + 1.2172)} \times 5,388 = 2,500 \text{ cu. ft.}$ (4) $\frac{1}{(1.0541 + 1.2172)} \times 5,388 = 2,888 \text{ cu. ft.}$
Pressure.	49	$p = k \left(X_1 + \frac{Q}{1} \frac{1}{1 - \left(X_3^2 + (X_3 + X_4)^2 \right)} \right)^2.$.0000000217 $\left(\frac{10,000}{.7471 + \frac{1}{\sqrt{.9428^2 + (1.0541 + 1.2172)^2}}} \right)^{\frac{2}{2}}$.8290 lb.
Power.	20	$u = k \cdot \frac{q^3}{\left(X_1 + \frac{1}{\sqrt{\frac{1}{X_2^2} + (X_3 + X_4)^2}}\right)^2}.$.0000000217 $ \frac{10,000^{1}}{\sqrt{\frac{1}{19428^{2}} + (1.0541 + 1.2172)^{2}}} $
Quantity.	51	$Q = \left(X_1 + \frac{1}{\sqrt{\frac{1}{X_2^2} + \frac{1}{(X_3 + X_4)^2}}}\right) \sqrt{\frac{p}{k}}$	$\left(\frac{.7471 + \frac{1}{\sqrt{\frac{1}{.9428^2} + \frac{1}{(1.0541 + 1.2172)^2}}}\right) \times \sqrt{\frac{.829}{.0000000217}} = 10,000 \text{ cu. ft.}$

PROPORTIONATE DIVISION.

Primary Splits (only).—(1) 4 ft. \times 5 ft., 800 ft. long = 3,500 cu. ft. 4 ft. \times 5 ft., 1,200 ft. long = 6,500 cu. ft.

To Find:	No	Formula.	Specimen Calculation.
Pressure due to	10	q ²	$\frac{3,500^{2}}{5,060^{2}} = .47845 lb.$
friction.	13	$p = \overline{X_p^x}$	(2) $\frac{6,500^8}{4,131^2} = 2.4757 \text{ lb.}$

To accomplish this division of air, the pressure in split (1) must be increased by means of a regulator to make it equal to the pressure in the free or open split (2), and, hence, the pressure due to the regulator is equal to the difference between the natural pressures in these splits.

Pressure due to the regulator in split (1).		$p = p_2 - p_1.$	2.4757 — .47845 = 1.99725 lb.
Area of the opening in regulator.	37	$A = \frac{.0004 q}{\sqrt{i}}.$	$\frac{.0004 \times 3,500}{\sqrt{\frac{1.99725}{5.2}}} = 2.259 \text{ sq. ft.}$

Secondary Splits.—(1) 4 ft. \times 5 ft., 800 ft.—3,500 cu. ft. (2) 4 ft. \times 5 ft., 500 ft.—6,500 cu. ft. (3) 4 ft. \times 5 ft., 400 ft.—4,000 cu. ft. (4) 4 ft. \times 5 ft., 300 ft.—2,500 cu. ft.

Note—When using the relative potential, multiply the result by k, to obtain the pressure, or the power.

Pressure due to friction. Free split-secondary pressure.
$$p = \left(\frac{q}{X_p}\right)^4.$$
 (1) $.000000217\left(\frac{3,500}{.7471}\right)^4 = .47848$ lb. (2) $.000000217\left(\frac{6,500}{.9428}\right)^2 = 1.0314$ lb. (3) $.000000217\left(\frac{4,000}{1.0541}\right)^2 = .31248$ lb. (4) $.000000217\left(\frac{2,500}{1.2172}\right)^2 = .091546$ lb.

Since the natural pressure in (3) is greater than that in (4), (3) is the free split, and its natural pressure is the pressure for the secondary splits. The pressure for the primary splits is then found by first adding the pressures in (2) and (3), and if their sum is greater than the natural pressure for (1), it becomes the pressure for he primary splits, or the mine pressure. If the natural pressure for (1) is the greater, this is made the free split, and it natural pressure becomes the primary or mine pressure. In this case, the secondary pressure must be increased by placing a regulator in split (3).

Primary or mine pressure.	$p_2 + p_3$.		1.0314 + .31248 = 1.34388.
Pressure due to the regula- tors.	$p_3 - p_4. \\ (p_2 + p_3) - p_1.$	(4) (1)	.31248 — .091546 = .220934 lb. (1.0314 + .31248) — .47848 = .86540 lb.
Areas of openings in the regulators.	$A = \frac{.0004 \ q}{\sqrt{i}}.$	(4)	$\frac{.0004 \times 2,500}{\sqrt{\frac{.220934}{5.2}}} = 4.8514 \text{ sq. ft.}$
		(1)	$\frac{.0004 \times 3,500}{\sqrt{\frac{.8654}{5.2}}} = 3.4328 \text{ sq. ft.}$

ETHODS AND APPLIANCES IN THE VENTILATION OF MINES.

Ascensional Ventilation.—Every mine, as far as practicable, should be venti-ted upon the plan known as ascensional ventilation. This term refer-articularly to the ventilation of inclined seams. The air should enter the at its lowest point, as nearly as possible, and from thence be conducted arough the mine to the higher points, and there escape by a separate haft, if such an arrangement is practicable. Where the seam is dippling onsiderably and is mined through a vertical shaft, the upcast shaft should be located as far to the rise of the downcast shaft as possible. The intake and the located as far to the rise of the downcast shaft as possible. s then first conducted to the lowest point of the dip workings, which it raverses upon its way to the higher workings. In the case of a slope working where a pair of entries is driven to the dip, one being used as the ntake and the other the return, there being cross-entries or levels driven at egular intervals along the slope, the air should be conducted at once to the nside workings from which point to de observed is to conduct the air-current from the riside workings from the inside, outwards. Where the development of the crossentries from the inside, outwards. Where the development of the crossentries or levels is considerable, their circulation is considered separately, and a fresh air split is made in the intake at each pair of levels. In all ventilation, the main point to be observed is to conduct the air-current first to the inside workings from whome it is distributed along the restrictions.

to the inside workings, from whence it is distributed along the working face as it returns toward the upcast.

General Arrangement of Mine Plan.—Every mine should be planned with respect to three main requirements, viz.: (a) haulage; (b) drainage; (c) ventilation. These requirements are so closely connected with one another that the consideration of one of them necessitates a reference to all. The mine should be planned so that the coal and the water will gravitate toward the opening, as far as possible. There are many reasons, in the consideration of non-gaseous mines, why the haulage should be effected upon the return airways. The haulage road is always a dusty road, caused by the traveling of men and mules, as well as by the loss of coal in transit, which becomes reduced to fine slack and powder. If the haulage is accomplished upon the intake entry or air-course, this dust is carried continually into the mine and working places, which should be avoided whenever possible. When the loaded cars move in the same direction as the return air, the ventilation of the mine is not as seriously impeded. It is often the case that fewer doors are required upon the return airway than upon the intake, which is a feature favorable to haulage roads. Again, in this arrangement, the hoisting shaft is made the upcast shaft, which prevents the formation of ice, and consequent delay in hoisting in the winter season. The arrangement, however, presupposes the use of the force fan or blower, since if a furnace or exhaust fan is employed, a door, or probably double doors, would have to be placed upon the main haulage road at the shaft bottom, which would be a great hindrance.

In the ventilation of gaseous mines, however, other and more important considerations demand attention. The gaseous character of the return current prevents making the return airway a haulageway. In such mines, the haulage should always be accomplished upon the intake air, as any other system would often result in serious consequences. In such gaseous mine, men and animals must be kept off the return airways as far as this is

possible.

As far as practicable, ventilation should be accomplished in sections or districts, each district having its own split of air from the main inteke, and its own return connecting with the main return of the mine. Reference has been made to this under Distribution of the Air in Mine Ventilation. has been made to this under Distribution of the air this splitting of the air-current is accomplished preferably by means of an This splitting of the air-current is accomplished preferably by means of an over crossing. There are, in air bridge, either an under crossing or an over crossing. There are, in general, three systems of ventilation, with respect to the ventilating motor employed: (a) natural ventilation; (b) furnace ventilation; (c) mechanical ventilation.

Natural ventilation means such ventilation as is secured by natural means, or without the intervention of artificial appliances, such as the furnace, or any mechanical appliances by which the circulation of air is maintained. In natural ventilation, the ventilating motor or air motor is an air column that exists in the downcast shaft by virtue of the greater weight of the downcast air. This air column acts to force the air through the airways of the mine. An air column always exists where the intake and currents of air pass through a certain vertical height, and have diffe temperatures. This is the case whether the opening is a shaft or a since, in either case, there is a vertical height, which in part determine the height of air column. The other factor determining the height of column is the difference of temperature between the intake and ret The calculation of the ventilating pressure in natural ventilation is ident with that of furnace ventilation, which is described later.

Ventilation of Rise and Dip Workings.—We have referred to the air colu existing either in vertical shafts or slopes as the motive column or ve lating motor. Such an air column will be readily seen to exist in any or dip workings within the mine, and may assist or retard the circular of the air-current through the mine. It is this air column that renders ventilation of dip workings easy, and that of rise workings corresponding difficult, depending, however, on the relative temperature of the intake return currents; the latter usually is the warmer of the two, which gi rise to the air column. The influence of such air columns must always taken into account in the calculation of any ventilation. This is of

neglected.

The influence of air columns in rise or dip workings, within the mit becomes very manifest where, from any reason, the main intake current increased or decreased. For example, a mine is ventilated in two splits, rise and a dip split; a current of 50,000 cu. ft. of air is passing in the man airway, 30,000 cu. ft. passing into the dip workings, and 20,000 into the ri workings. A fall of roof in the main intake airway, or other cause, reduce the main current from 50,000 to 35,000 cu. ft. Instead, now, of 21,000 cu. going to the dip workings and 14,000 to the rise workings, we find that this proportion no longer exists, but that the dip workings are taking more that their proportion of air, and the rise workings less. Thus, the circulation being decreased to 35,000 cu. ft., the dip workings will probably take 25,000 cu. ft., and the rise workings 10,000 cu. ft. On the other hand, had the intake current been increased instead of decreased, the rise workings would intake current been increased instead of decreased, the rise workings would then take more than their proportion, while the dip workings would take less. The reason for this distribution is evident; suppose, for example, the intake or mine pressure is 3 in. of water gauge, and in. the dip workings there is \(^1\) in. of water gauge, and in. the dip workings there is \(^1\) in. of water gauge acting to assist ventilation, while a like water gauge of \(^1\) in. in the rise workings acts to retard ventilation. The effective water gauge in the dip workings is therefore 3\(^1\) in., while the effective water gauge in the rise workings is 2\(^1\) in., or they are to each other as 7:5. If, now, the mine pressure is decreased to, say, 2 in., the effective rise and dip pressures will be, respectively, 2\(^1\) in. and 1\(^1\) in., or as 5:3. We observe, before the decrease, the dip pressure was \(^1\), or 1.4, times the rise pressure, while after the decrease took place in the mine pressure, the dip pressure became \(^1\), or 1.66, times the rise pressure. The relative quantities passing in the dip split before and after the decrease took place, as compared with the observations of the pressure of the pressure of the contractive of the pressure of the

quantities passing in the rise split, will be as the $\sqrt{1.4}$: $\sqrt{1.66}$, showing an increase of proportion. Now, instead of a decrease taking place in the mine pressure, let us suppose it is increased, say, from 3 in. to 4 in. The effective pressures in the dip and rise workings will then be, respectively, 4 in. and 34 in., or they will be to each other as 9:7, instead of 7:5. Here we observe that the dip property in 12. observe that the dip pressure is 13, or 1.15, times the rise pressure, instead The relative quantities, therefore, passing in the dip split, before and after the increase of the mine pressure, as compared with the quantities

passing in the rise split, will be in the ratio of $\sqrt{1.4}$: $\sqrt{1.15}$, showing a decrease of proportion. We observe that any alteration of the mine pressure by which it is increased or decreased does not affect the inside dip or rise columns, and hence the disproportion obtains. In case of a decrease of the mine pressure, the dip workings receive more than their proportion of air, and in case of an increase of the mine pressure, they receive less than their proportion of air.

Influence of Seasons.—In any ventilation, air columns are always established in slopes and shafts, owing to the relative temperatures of the outside and inside air. The temperature of the upcast, or return column, may always be assumed to be the same as that of the inside air. The temperature of the downcast, or intake column, generally approximates the temperature of the outside air, although, in deep shafts or long slopes, this temperature may be changed considerably before the bottom of the shaft or slope is reached, and

Onsequently the average temperature of the downcast, or intake, is often ifferent from that of the outside air. The difference of temperatures will lso vary with the season of the year. In winter the outside temperature is below that of the mine, and the circulation in shafts and slopes is assisted, since the return columns are warmer and lighter than the intake columns For the same circulation. In the summer season, however, the reverse of this is the case. The course of the air-current will thus often be changed. When the outside temperature approaches the average temperature of the mine, there will be no ventilation at all in such mines, except such as is

caused by accidental wind pressure.

In furnace ventilation the temperature of the upcast column is increased above that of the downcast column by means of a furnace. The chief points to be considered in furnace ventilation are in regard to the arrangement and size of the furnace. Furnace ventilation should not be applied to gaseous seams, and in some cases is prohibited by law. It is, however, in use in many mines liberating gas. In such cases the furnace fire is fed by a current of air taken directly from the air-course, sufficient to maintain the fire, and the return current from the mine is conducted by means of a dumb drift, or an inclined passageway, into the shaft, at a point from 50 to 100 ft. above the seam. At this point, the heat of the furnace gases is not sufficient for the ignition of the mine gases. The presence of carbonic acid gas in the furnace gases also renders the mine gases inexplosive. In other cases, where the dumb drift is not used, a sufficient amount of fresh air is allowed to pass into the return current to insure its dilution below the explosive point before it reaches the furnace.

Construction of a Mine Furnace.—In the construction of a mine furnace, a sufficient area of passage must be maintained over the fire and around the furnace to allow the passage of the air-current circulating in the mine. The velocity of the current at the furnace should be estimated not to exceed 20 ft. per second, and the entire area of passage calculated from this velocity. Thus, for a current of 50,000 cu. ft. of air per minute, the area of passage

through and around the furnace should be not less than

$$\frac{50,000}{60 \times 20} = 41$$
 sq. ft.

This is a safe method of calculation, notwithstanding the fact that the velocity of the air is often much more than 20 ft. per second, yet the volume

of the air is largely increased owing to the increase of temperature.

The length of the furnace bars is limited to the distance in which good firing can be accomplished, and should not exceed 5 ft. The width of the grate will therefore determine the grate area. The grate area must, in every case, be sufficient for the heating of the air of the current to a temperature such as to maintain the average temperature of the furnace shaft high enough to produce the required air column, or ventilating pressure, in the mine. The area A of the grate of the furnace is best determined by the formula

$$A = \frac{34}{\sqrt{D}} \times \text{H. P.}$$
, in which $A = \text{grate area in square feet; H. P. = horse-}$

power of the circulation; and D= depth of shaft in feet. The horsepower for any proposed circulation may always be determined by dividing the quantity of air (cubic feet per minute) by the mine potential X_u , and cubing and dividing the result by 33,000; thus,

H. P. = $\left(\frac{q}{X_u}\right)^3 \times \frac{1}{33,000}$

The furnace should have proper cooling spaces above and at each side; upon one side, at least, should be a passageway or manway. The furnace should be located at a point from 10 to 15 yd. back from the foot of the shaft, at a place in the airway where the roof is strong. This is well secured by railroad iron immediately over the furnace. A good foundation is obtained in the floor, and the walls of the furnace carried up above the level of the grate bars, when the furnace arch is sprung. If possible, a full semicircle should be used in preference to a flat arch. The sides and arch of the furnace should be carried backwards to the shaft; this is necessary in order to prevent ignition of the coal. The walls and arch are constructed of firebrick a sufficient distance from the furnace, and afterwards of a good quality of hard brick; the shaft is also lined with brick or protected by sheet iron a sufficient height to prevent the ignition of the curbing.

Air Columns in Furnace Ventilation.—As previously stated, natural ventilation deformed and furnace ventilation are identical, in so far as in each the ventilation. motor is an air column. This air column is an imaginary column of whose weight is equal to the difference between the weights of the upsal and downcast columns. The upcast and downcast columns in furniventilation are sometimes referred to as the primary and secondary columns, respectively. The primary of furnace column is, in nearly ever case, a vertical column, and consists of a single air column whose average temperature is easily approximated. According to the manner of opening the mine, whether by shaft, slope, or drift, the secondary column may a vertical column in the shaft, an inclined column in the slope, or an outside air column in case of a drift opening. Again, it is to be observed that case of a slope opening where the top of the furnace shaft is much high than the mouth of the slope, and the dip of the slope is considerable, the secondary column consists of two columns of different temperatures, soutside air column and the slope column. These two parts of the secondary column the leptor of the top of the furnace shaft determine the secondary column. The level of the top of the furnace shaft determine the top of both the primary and secondary columns, whether these columns motor is an air column. This air column is an imaginary column of the top of both the primary and secondary columns, whether these column are in the outer air or in the mine. The weight of the upcast or primar column is largely affected by its gaseous condition. For example, if the return current from the mine is laden with blackdamp CO_2 , its weight will be much increased, since this gas is practically 14 times as heavy as air



while, if laden with marsh gas, or firedamp mix ture, its weight will be considerably reduced. These causes decrease and increase, respectively, the ventilating pressure in the mine.

Inclined Air Columns.—In a slope opening, the air column is inclined; it is none the less, however, an air column, and must be calculated in the same manner as a vertical column whose ver-

Fig. 7. the same manner as a vertical column whose vertical height corresponds to the amount of dip of the slope, the air column in each of these being the same for the same temperature. The air column in all dips and rises must be estimated in like manner, by ascertaining the vertical height of the dip.

Calculation of Ventilating Pressure in Furnace Ventilation.—The ventilating pressure in the mine airways, in natural or in furnace ventilation, is caused by the difference of the weights of the primary and secondary columns. As a lower moves from a point of higher pressure toward a point of lower always moves from a point of higher pressure toward a point of lower pressure, and this movement of the air is caused by the difference between these two pressures. In this calculation each column is supposed to have an area of base of 1 sq. ft. Hence, if we multiply the weight of 1 cu. ft. of air at a given barometric pressure, and having a temperature equal to the average temperature of the column, by the vertical height D of the column. we obtain not only the weight of the column but the pressure at its base due to its weight. Now, since the ventilating pressure per square foot in the airway is equal to the difference of the weights of the primary and secondary columns, we write

 $p = \left(\frac{1.3253 \times B}{459 + t} - \frac{1.3253 \times B}{459 + T}\right) \times D.$

EXAMPLE.—Find the ventilating pressure in a mine ventilated by a furnace, the temperatures of the upcast and downcast columns being respectively, 350° F. and 40° F., the depth of the upcast and downcast shafts being each 600 ft., and the barometer 30 in.

Substituting the given values in the above equation, we have

$$p = 1.3253 \times 30 \times 600 \left(\frac{1}{459 + 40} - \frac{1}{459 + 350} \right) = 18.32 \text{ lb. per sq. ft.}$$

Calculation of Motive Column or Air Column.—It is often convenient to express the ventilating pressure p (lb. per sq. ft.) in terms of air column or motive column M, in feet. The height of the air column M is equal to the pressure p divided by the weight w of 1 cu. ft. of air, or $M = \frac{p}{w}$. The expression for motive column may be written either in terms of the upcast air or

of the downcast air, the former giving a higher motive column than the latter for the same pressure, since the upcast air is lighter than that of the

As the surplus weight of the downcast column of air produces the ventilating pressure, it is preferable to write the air column in terms of the downcast air, or, in other words, to consider the air column as being located in the downcast shaft, and pressing the air downwards and through the airways of the mine. If we divide the expression previously given for the

ventilating pressure by the weight of 1 cu. ft. of downcast air $\left(\frac{1.3253 \times B}{459 + t}\right)$,

we obtain for the motive column, after simplifying, $\mathbf{M} = \left(\frac{T-t}{459+T}\right) \times D$, which is the expression for motive column to the expr which is the expression for motive column in terms of the downcast air.

If, on the other hand, we divide the expression for the ventilating pressure by the weight of 1 cu. ft. of upcast air $(\frac{1.3253 \times B}{459 + T})$, we obtain

 $M = \left(\frac{T-t}{459+t}\right) \times D$, which is the expression for motive column in terms of

influence of Furnace Stack.—To increase the height of the primary or furnace column, a stack is often erected over the mouth of the furnace shaft. The effect of this is to increase the ventilating pressure in the mine in proportion to the increased height of the primary column, and to increase the quantity of air passing in the mine in proportion to the square root this height. Thus, the square root of the ratio of the heights of the primary column, before and after the stack is erected, is equal to the ratio of the quantities of air passing before and after the erection of the stack. Or, calling these quantities q_1 and q_2 , and the height of stack d, we have

$$\sqrt{\frac{D+d}{D}} = \frac{q_2}{q_1}$$
, or $q_2 = \sqrt{\frac{D+d}{D}} \times q_1$.

MECHANICAL VENTILATORS.

A large number of mechanical ventilators have been invented and applied, with more or less success, to the ventilation of mines. The earliest type of ventilator was the wind cowl, by which the pressure of the wind at the surface was brought to bear effectively upon the mine airways by the action of a cowl whose mouth could be turned toward the wind; this was naturally very unreliable. The waterfall was also extensively applied at one time, but very unreliable. The waterflat was also extensively applied at one time, out its application could only be made where there was a reliable source of water supply, and where the drainage of the mine could be effected through a tunnel, or where the mine opening could be placed in connection with such a waterfall outside of the mine. Where these conditions are obtained, as is the case in some mountainous districts, the waterfall is still in use, as the are effective means of varificition, and is economical. Its application it is an effective means of ventilation, and is economical. Its application, however, must be limited to the ventilation of small mines. The steam jet is another mechanical device for producing an air-current in the min. The steam is allowed to issue from a jet at the bottom of an upcast shaft, and steam is allowed to issue from a jet at the bottom of an upcast shart, and, by the force of its discharge, causes an upward current in the shaft. Its use, however, is very limited, and is practically restricted to the ventilation of shafts while sinking. In this connection it may be mentioned, however, that the discharged steam from the mine pumps, where practicable, may be conducted into the upcast shaft; or the discharge pipe from the pumps may be carried up the upcast shaft, is heat increasing the temperature of the shaft, and thereby increasing the motive column and the ventilation.

Fas Ventilation—Mechanical motors of this type present two distinct.

Fan Ventilation.— Mechanical motors of this type present two distinct modes of action in producing an air-current: (a) by propulsion of the air; and (b) by establishing a pressure due to the centrifugal force incident to the revolution of the fan. Fans have been constructed to act wholly on one or the other of these principles, while others have been constructed to act on both of these principles combined.

Disk Fans.—The action of this type of fan resembles that of a windmill, except that in the latter the wind drives the mill, while in the former the fan propels the air or produces the wind. This type of fan consists of a number of vanes radiating from a central shaft, and inclined to the plane of revolution. The fan is set up in the passageway between the outer air and the mine airways. Power being applied to the shaft, the revolution of the

vanes propels the air, and produces a current in the airways. The fan m force the air through, or exhaust the air from, the airways, according to direction of its revolution. This type of fan is most efficient under lig pressures. It has found an extensive application in mining practice, a has a large number of devotees, but has been replaced to a large degr in the ventilation of extensive mines. This type of fan acts wholly

propulsion.

Centrifugal fans include all fans that act solely on the centrifugal principled those that combine the centrifugal and propulsion principles. The and those that combine the centrifugal and propulsion principles. The action of the fan, whether by centrifugal force alone, or combined wife propulsion, depends on the form of the fan blades. In this type of fan, the blades are all set at right angles to the plane of revolution, and not inclined as in the disk fan just described. The blades may, however, be either radial blades, sometimes spoken of as paddle blades, or they may be inclined to the radius sitter forward in the direction of revolution or belowerd. radius either forward in the direction of revolution, or backward. Whe the blades are radial, the action of the fan is centrifugal only. The incline tion of the blades backward from the direction of motion gives rise to a action of propulsion, in addition to the centrifugal action of the fan. The blades in this position may be either straight blades in an inclined position as in the original Guibal fan, or they may be curved backward in the form of a spiral, as in the Schiele and Waddle fans.

Centrifugal fans may be (a) exhaust fans or (b) force fans or blowers. In each, the action of the fan is essentially the same; i. e., to create a difference of pressure between its intake or central opening, and its discharge at the circumference. The centrifugal force developed by the revolution of the air between the blades of the fan causes the air within the fan to crowd toward the circumference; as a result, a depression is caused at the center and a compression at the circumference, giving rise to a difference of pressure between the intake and the discharge of the fan.

Exhaust Fans.—If the intake opening of the fan be placed in connection with the mine airways, and the discharge be open to the atmosphere, the fan will act to create a depression in the fan drift leading to the mine, which will cause a flow of air through the mine airways and into and through the fan. In this case, the fan is exhausting, its position being ahead of the current that it produces in the airway. The atmospheric pressure at the intake of the mine forces the air or propels the current toward the depression in the first desired by the formation of the mine forces the air or propels the current toward the depression in the formation of the form

depression in the fan drift caused by the fan's action.

Force Fans and Blowers.—If the discharge opening of the fan be placed in connection with the mine airways, a compression will result in the fan drift owing to the fan's action, and the air will flow from this point of compression through the airways of the mine, and be discharged into the upcast, and thence into the atmosphere. The ventilating pressure in the case of either the exhaust fan or the force fan is equal to the difference of pressure in the case of either the case of the created by the fan's action. In the former case, when the fan is exhausting, the absolute pressure in the fan drift is equal to the atmospheric pressure less the ventilating pressure, while in the latter case, when a fan is forcing, the absolute pressure in the fan drift is equal to the atmospheric pressure increased by the ventilating pressure. This gives rise to two distinct systems of ventilation, known as (a) vacuum system and (b) plenum system.

Vacuum System of Ventilation .- In this system, the ventilation of the mine is accomplished by creating a depression in the return airway of the mine. This depression may be created by the action of an exhaust fan, as just described, or by the action of a furnace. In either case, the absolute pressure in the mine is below that of the atmosphere, or, we may say, the mine is ventilated under a pressure below the atmospheric pressure. This system has many points of advantage over the plenum system, and for years was considered by many the only practicable system of ventilation. Its appli-cation, however, is controlled by conditions in the mine with respect to

the gases liberated, the arrangement of the haulage system, etc.

Plenum System of Ventilation.—In this system, the air-current is propelled through the mine airways by means of the compression or ventilating pressure created at the intake opening of the mine. This ventilating pressure may be established by a fan, waterfall, wind cowl, or any other mechanical means at hand. In this system, the absolute pressure in the mine is about the office that the other than the control of the mine is about the state of the atmosphere or water the absolute pressure in the mine. is above that of the atmosphere; or, as we say, the mine is ventilated under a pressure above the atmospheric pressure.

Comparison of Vacuum and Pienum Systems.—No hard-and-fast rule can be made to apply in every case, as each system has its particular advantages. In case of a sudden stoppage of the ventilating motor at a mine, there is, in the vacuum system, a rise of mine pressure, instead of a fall, and the gases are driven back into the workings for a while, while, in the plenum system, any stoppage of the ventilating motor is followed at once by a fall of pressure in the mine, and mine gases expand more freely into the passageways at the very moment when their presence is most dangerous. This point must be carefully considered in the ventilation of deep workings. In shallow workings, the plenum system is often advantageous, especially if there is a large area of abandoned workings that have a vent or opening to the atmosphere, either through an old shaft or through crevices extending to the surface. Every crevice or other vent becomes a discharge opening by which the mine gases find their way to the surface, and the gases accumulating in the old workings are driven back into the workings, and find their way to the surface and the gases accumulating in the old workings are driven back into the workings, and find their ways to the surface and the gases are under the surface of way to the surface instead of being drawn into the mine airways, as would be the case in an exhaust system. Any given fall of the barometer affects the expansion of mine gases to a less extent in the plenum system than in the vacuum system, but this small advantage would not give it consideration in determining between the adoption of the one or the other of these two systems; regard must be had, however, to other conditions more vital than this. In the ventilation of gaseous seams, owing to the necessity of making the intake airway the haulage road, the exhaust system has usually been adopted, as the main road is thereby left unobstructed by doors. .

TYPES OF CENTRIFUGAL FANS.

We shall only mention the more prominent types of fans that have been or are still in use, giving the

characteristic features, as nearly as possible, of each fan. Many fans have been built, however, combining many of the features that originally characterized a single type of fan.

Nasmyth Fan.—Fig. 8 is the

original type of fan representing straight paddle blades radiating from the center, which is its characteristic feature. This was probably the earliest attempt to apply the centrifugal principle to a mine ventilator, and although not recognized at the

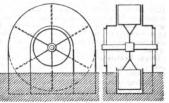
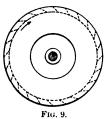


FIG. 8.

time, the fan embodied some of the most essential principles in centrifugal It possessed certain disadvantages, however, chief of which was central or intake opening. The blades, also, were straight throughout their entire length, being normal both to the inner and outer circles of the fan, a contracted central or intake opening.

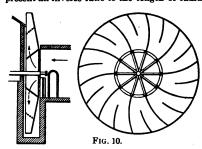


and thus did not provide for receiving the air without shock at the throat of the fan. The depth of Nasmyth's blades equaled one-half the radius of the fan, which was, under ordinary conditions of mine practice, far too great, and gave the fan a low efficiency.

Biram's Ventilater. — About 1850, Biram attempted to improve upon the Nasmyth ventilator by reducing the depth of blade so that it was but one-tenth of the radius. The blades were straight, as in Nasmyth's ventilator, but inclined backwards from the direction of motion at a A large number of these d. This fan was run at a considerable angle.

blades were employed. This fan was run at a considerable speed, but proved very inefficient. It depended more on the effort of propulsion given to the air than on the centrifugal principle, as the depth of the blade was as much too small as that of Nasmyth's was too great. The intake or central opening in this fan was as contracted as in the former type. See Fig. 9.

Waddle Ventilator.—In this fan, Fig. 10, the inventor attempted to reenforce the discharge pressure at the circumference against the pressure of the atmosphere. The discharge took place all around the entire circumference of the fan, which was entirely opened to the atmosphere. The blades were curved backward from the direction of motion in spiral form. The widt of the blade decreased from the throat toward the circumference, so as to present an inverse ratio to the length of radius.



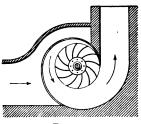
Thus, the area of passage between the fan blades was maintained constant from the throat to the circumference of the fan. The pur-pose of this was to maintain the velocity of the air through the fan constant, and to fortify the pressure due to the fan against the atmospheric pressure at the point of discharge. The es-The essential features of the Waddle ventilator were, therefore, curved blades tapered toward the circumference. and a free discharge into the atmosphere all around the circumference. type is the best type of the

open-running fan having no peripheral casing, and discharging air into the atmosphere all around the circumference.

Schiele Ventilator.—This ventilator, Fig. 11, was constructed on the same principles as the Waddle ventilator just described, but differed from the latter, as the discharge was made into a spiral chamber surrounding the fan and leading to an expanding or evasé chimney. There was some advantage in this feature, as it protected the fan against the direct influence of the atmosphere, and reduced the velocity of discharge; but, in each of these fans, the intake opening was contracted, and the depth of blade was

very great, yielding a comparatively low efficiency.

Geibal Ventilator.—The next important step in the improvement of centrifugal ventilators was introduced by M. Guibal, who constructed a fan.
Fig. 12, embodying the features of the Nasmyth ventilator, with the addition of a casing built over the fan to protect its circumference. This casing was, however, a tight-fitting casing, and as such, differed very materially from the Schiele casing. In the Guibal fan the blades were arranged upon a series of parallel bars passing upon each side of the center and at some distance from it. By this construction, the blades were not radial at their inner edge or the throat of the fan. They were curved, however, as they approached the circumference of the fan, so as to be normal or radial at the circumference.



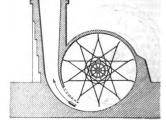


FIG. 11. FIG. 12.

The advantage of this construction was to give a strong skeleton or framework to the revolving parts, and, further, each blade was inclined to the radius at its inner extremity, the effect of which was to receive the air upon the blade with less shock than was the case in the Nasmyth ventilator. intake or central opening, however, was very contracted, and the tight-fitting casing about the circumference prevented the effective action of the fan during a considerable portion of its revolution. The fan was supplied with an évasé chimney, which was a feature of the Schiele fan, but vibration was so strong that a shutter was required at the cut-off below

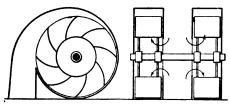


Fig. 13.

the chimney, to prevent it. This shutter was made adjustable, and is known

as the Walker shutter, having been applied to the fan later.

The Guibal ventilator presents some important and valuable features in the protecting cover, and in the blades meeting the outer circumference radially, and in the air being received with less shock than before. On the whole, it has proved a very efficient ventilator, although much work is lost by reason of its contracted central orifice and tight casing, where the same is used.

Murphy Ventilator.—Fig. 13 consists of twin fans supported on the same shaft and set a few feet apart. Each fan receives its air on one side only, the openings being turned toward each other. This ventilator is built with a small diameter, and is run at a high speed. The blades are curved backwards from the direction of motion. The intake opening is considerably enlarged; a spiral casing generally surrounds the fan, and in every respect this fan makes an efficient high-speed motor. It has received considerable favor in the United States, where it has been introduced into a large number of mines.

as little understood in regard to their principle of action as the Capell fan. The fan is constructed along the lines of the Schiele ventilator, but differs from that ventilator in the manner of receiving its intake air and delivering the same into the main body of the fan. Here, and revolving with it, is a set of smaller supernumerary blades. These blades occupy a cylindrical space within the main body of the fan, and are inclined to the plane of revolution so as to assist in deflecting the entering air through small ports or openings into the main body of the fan, where it is revolved and discharged at the circumference into a spiral space resembling that surrounding the Schiele fan. The larger blades of this

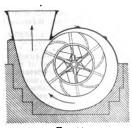


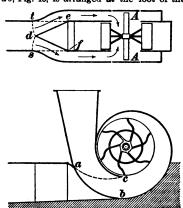
Fig. 14.

Schiele fan. The larger blades of this fan are curved backwards as the Schiele blades, but are not tapered toward the circumference. The fan is capable of giving a high water gauge, and is efficient as a mine ventilator. The space surrounding the fan is extended to form an expanding chimney. The fan may be used either as an exhaust fan or a blower. The best results in the United States have been obtained by blowers. In Germany, where this fan is in general use, there are no blowers.

The position of the fan, whether used as an exhaust or blower, should be sufficiently removed from the fan shaft to avoid damage to the fan in case of explosion in the mine. Even in non-gaseous

plosion in the mine. Even in non-gaseous mines, the fan should be located a short distance back from the shaft mouth, to avoid damage due to settlement. Connection should be made with the fan shaft by means of an ample drift, which should be deflected into the shaft so as to produce as little shock to the current as possible. In

case of gaseous seams, explosion doors should be provided at the shaf mouth. The ventilator at every large mine should be arranged so that i may be converted from an exhaust to a blow-down fan at short notice This is managed by housing the central orifices or intake of the fan in such a manner as to connect them directly with the fan drift. A large door ab, Fig. 15, is arranged at the foot of the expanding chimney, the latter



being placed between the far the shaft. and This door when the fan is exhausting is in the lower position ab and then forms a portion of the spiral casing leading to the chimney. When the fan is blowing, however, the door is swung upwards so as to occupy the position ac, being tangent to the cut-off at c thereby closing the discharge into the chimney and causing it to enter the fan drift behind the door. At the same time the positions of the two doors ed and fd, in the fan drift, are changed to et and fs, respectively, to open the fan drift to the discharge from the fan and to close the openings lead ing from the fan drift to the housing upon each side of the fan, while another set of door.

A A upon each side of the fan.

Fig. 15.

Fig. 15.

The housing, which were previously closed tightly, are now set wide open to admit the outside air to the intake openings of the fan. The fan is thus made to draw its air from the atmosphere, and discharge it into the fan drift, instead of

drawing its air from the fan drift and discharging into the chimney, as before.

The manometrical efficiency of a fan is the ratio between its effective and theoretical pressures. It has been assumed that the theoretical pressure due $\hat{u}^2 \times 1.2 \times 12$

 $\frac{1}{g}$, or i =to the fan's action is given by the equation h = $g \times 1,000$ u being, as before, the tangential speed (feet per second), and g the force of gravity (32.16); h = head of air column in feet; i = water gauge in inches.

gravity (32.16); h = head of air column in feet; i = water gauge in inches. The term mechanical efficiency, as applied to the ventilator, is the ratio between its effective and theoretical powers. In estimating the efficiency of a ventilator, it is customary, though incorrect, to estimate the theoretical power of the fan from an engine card taken from the steam cylinder of the fan engine. The efficiency of the steam engine is thus confused with the efficiency of the ventilator. Mr. Beard gives the following formula for the theoretical work of the fan per minute: $U = .001699 \frac{m^3 - 1}{m^3} \sqrt{VR} ^3 b n^2$,

in which m = ratio between outer and inner diameters of fan (D = md). and V = velocity (feet per minute) of air in fan drift; R = outer radius of fan blades (feet); b = breadth of fan blades (feet); n = number of revolutions of fan per minute. If we divide the power upon the air, as determined by the expression q p, by the theoretical work given in the last equation, we obtain the value of the coefficient of efficiency. According to this formula the efficiency of the ventilator changes with the speed, decreasing as the speed increases, but not in the same ratio. An expression for the coefficient

of efficiency of a ventilator is given by Beard as follows: $K = \frac{160,000^{\circ}}{c X^3 + 163,600^{\circ}}$

The factor c is a constant of design whose value may vary from 2 to 7, but for an ordinary design, the value c = 4 may be taken. This factor has reference to the equipment of the machine with respect to its efficiency for passing an air-current through itself with least resistance. Thus, where the ventilator is to be equipped with intake blades for the deflection of the aircurrent into the motor, and with straight radial blades having only a forward

Curve at the lip of the blade to avoid the shock of the entry air against the revolving blades, and the spiral casing starting a short distance upon the cut-off and extending uniformly around the circumference of the fan, the value of this constant may be 2 or 3. Where none of these accessories to the efficiency of the fan is employed, the value of c may be as high as 7.

FAN CONSTRUCTION.

Size of Central Orifice.—The velocity of the intake should vary between 1,000 ft. and 1,500 ft. per minute, while 1,200 ft. may be used for fan calculations. If d = diameter of opening, and q = quantity of air passing per

minute, $d = \sqrt{\frac{q}{1,200 \times .7854}}$ for single-intake fans, and $d = \sqrt{\frac{q}{2,400 \times .7854}}$ for double-intake fans.

Upon entering the fan the air travels in a radial direction; this change of direction is accompanied by a slight reduction of the velocity, hence the throat area of the fan must be slightly in excess of the intake area. The throat is the surface of the imaginary cylinder that has for its two bases the two intake openings of the fan, and for its length the width of the fan, $\pm ab$. The throat area is commonly made 1.25 times the total area of the intake orifices, which gives for breadth of blade $b = \frac{1}{2} d$ for double intake, $- Rand b = \frac{1}{2} d$ for double intake,

and $b = \frac{1}{6} d$ for single intake.—Beard.]

Diameter of Fan.—Murgue assumes the tangential velocity of the blade tips (u) to create a depression double that due to the velocity as expressed

by the equation $H=\frac{u^2}{g}$, or if the manometrical efficiency = K, and the

effective head produced $= h, h = KH = K\frac{u^2}{g}$, or $u = \sqrt{\frac{gh}{K}}$. From this equation, the tangential velocity (feet per second) may be calculated for any given effective head h. This effective head h is the head of air column effective in producing the circulation in the airway. To convert the effective head of air column into inches of water gauge (i), we have 1,000

 $h = \frac{1.2 \times 12}{1.2 \times 12} i$. Having found the tangential speed required in feet per second, this is multiplied by 60, to obtain the speed in feet per minute, and dividing this result by the desired number of revolutions per minute, or the desired speed of the ventilator, the outer circumference of the fan blades is obtained. No reference is made in the equation to the quantity of air in circulation, which is determined from the equivalent orifice of

of air in circulation, which is determined from the case of air in circulation, which is determined from $V = \frac{.65 \sqrt{2 \, K} \, a \, u}{\sqrt{1 + \frac{a^2}{o^2}}}$, in which

V= volume of air (cu. ft. per sec.); a= equivalent orifice of the mine: o= the equivalent orifice of the fan. M. Murgue also uses the equation -, and suggests that the value of K for any particular type of

machine should be first decided, after which the tangential speed required to produce any given effective head of air column (h) is easily calculated

from the formula $u=\sqrt{\frac{g}{K}}$. The breadth of the blade is left largely to judgment, while this method of calculation gives the same size of fan for any given effective head desired, regardless of the quantity of air to be circulated, which is the same as saying that the ventilator will present the same efficiency when a large amount of air is crowded through its orifice of passage as when a smaller amount of air is necessary.

Mr. Beard uses the following formulas for determining the several dimensions of v and v and v are the following formulas for determining the several dimensions of v and v and v.

sions of a ventilating fan:

$$m = \sqrt[8]{\frac{Q}{n^2\sqrt{V}}\left(c + \frac{163,600^2}{X^3}\right) + 1}; \qquad D = \frac{m}{\sqrt{m^3 - 1}} \frac{3,770\sqrt{p}}{n\sqrt[4]{K^2V}};$$

$$b = \frac{385,000,000\ p}{(m^3 - 1)\ n^2\ K\ 1/\sqrt{Q\ V}}; \qquad e = \frac{\sqrt{m^3 - 1}}{170\ m} \sqrt[4]{\frac{X^3\ K^2\ V}{p}};$$

in which $m = \frac{D}{d}$, which is the ratio between the outer diameter of the fix

blades D and the inner diameter of the blade d, which equals the **diameter** of the intake orifice; b = width of fan blade; e = expansion of spiral casing a =

point of cut-off.

The other symbols stand for the same quantities as previously indicated. Curvature of Blades.—It was at one time supposed that the curvature of the blades should be such that the radial passage of the air-current would be undisturbed by the revolution of the fan; but fans-constructed on the principle gave no adequate results, and the theoretical spiral thus developed was entirely abandoned. A certain curvature of the blade backward, however, is assumed by many to increase the efficiency of the fan. This has not been proved in practice, but the effect of the backward curvature appears simply to necessitate a higher speed of revolution in the fan, in order to obtain the same results as are obtained with radial blades.

The Guibal blade, radial at its outer extremity, or normal to the outer circumference, and curved forward in the direction of motion, at its inner extremity, so that the lip of the blade approaches tangency to the throat

circle, seems the most effective blade in centrifugal ventilation.

Tapered Stades.—The object of the taper is to produce a constant area of passage from the throat to the circumference of the fan, and thus prevent the reduction of the velocity of the current in its passage through the fan. This feature presents an attempt similar to that attempted by the curvature of the blades, to hasten the passage of the air through the fan. It has not been proved, however, to have produced any beneficial result, except in the strengthening of the discharge pressure against the atmospheric pressure, in open-running fans. On the other hand, the slowing up of the air in its passage through a covered fan has by no means been proved a detriment, but is assumed by many to be an advantage, inasmuch as the air thus remains longer within the influence of the fan blades.

The number of blades depends on the size of the fan. An increased number strengthens the fan's action at the circumference, or supports the air at that point, and thus prevents the backlash or the reentry of air into the fan. due to the eddies occurring at the circumference when the blades are too far apart. To a certain extent, the number of blades is modified by the speed of revolution, high-speed motors requiring a somewhat lesser number, while low-speed motors require more. In any case, the number of blades should not be so great as to abnormally increase the resistance to the air-current. In general, the distance upon the outer circumference from tip to tip of the fan blades should be from 2 to 3 times the depth of the blade.

The spiral casing gradually reduces the velocity of the air and reduces the shock incident to the discharge of the air into the atmosphere. The spiral casing should be so proportioned that the velocity of the flow from the fan blades will be maintained constant around the entire circumference, and this should not be less than the velocity of the blade tips. The expansion of the casing at the cut-off should be such as to provide a velocity of the air at this point equal to the velocity of the blade tips, according to the

equation $e = \frac{Q}{\pi D n b}$, in which D = diameter of fan; n = number revolu-

tions per minute; b =breadth of fan blade.

The evase chimney reduces the velocity of the air, as it is discharged into the atmosphere, to a minimum. The chimney should be sufficiently high to protect the fan from the effect of high winds, but should not extend too far above the fan casing, the point of cut-off being situated below this, at about the level of a tangent to the throat circle at its lower side.

High-Speed and Low-Speed Motors.—The question of speed of the ventilating motor is largely an open one, inasmuch as the same work may be performed by a small ventilator running at a high speed as is performed by

a large ventilator running at a low speed.

It is important to design a mine ventilator at a speed such as to admit of its being increased in case of emergency. If the ventilator has been designed at a high speed, a demand for an increase of speed cannot be met as readily as when the ventilator is designed at a medium or low speed; in other words, the exigencies of mine ventilation demand that a ventilator shall be capable of greatly increased speed.

Fan Tests.-A large number of fan tests have been made, from time to

time, on different types of fans and under different conditions, with respect to the resistance against which the fan is operated, and the quantity of all recupiring the speed of the ventilator. The experiments have resulted, to a large extent, in tabulating a mass of contradictory data. The conditions that affect the yield of the centrifugal ventilator are so numerous, and the tabulation of the necessary data has been so often neglected in these experiments, as to render them practically useless for the purpose of scientific investigation. In conducting a reliable fan test, the following points should be observed: (1) Take the velocity, pressure, and temperature of the air at the same point in the airway, as nearly as practicable. point should be selected near the foot of the downcast shaft, or in the fan drift at a suitable distance from the fan, to avoid oscillations of pressure and (2) The area of the fan drift should be uniform for a suitable distance in each direction from the point of observation, and this area should be carefully measured. (3) Take the anemometer readings at different positions in the airway, so as to obtain an average reading over the entire sectional area. Do not interpose the body in this area so as to decrease the sectional area of the airway. (4) Take outside temperature of the air and the barometric pressure at the time of making the test. (5) The intake and discharge openings of the fan should be protected against wind pressure. (6) At least three observations should be made, at as many different speeds of the ventilator, and the number of revolutions of the fan carefully observed and recorded for each observation.

Mr. R. Van A. Norris (Trans. A. I. M. E., Vol. XX, page 637) gives the results of a large number of experiments performed upon different mine ventilating fans. This table, like all other tabulated fan tests, shows a large amount of contradictory data. The conclusions drawn by Mr. Norris from these tests are interesting and would be given here excepting that they might be misleading if considered apart from the description of the experi-

ments and the discussion leading up to the conclusions.

CONDUCTING AIR-CURRENTS.

Doors.—A mine door is used for the purpose of deflecting the air-current from its course in one entry so as to cause it to traverse another entry, at the same time permitting the passage of mine cars through the first entry. The essential points in the construction of a mine door are that it shall be hung from a strong door frame in such a manner as to close with the current. The door should be hung so as to have a slight fall. If necessary, canvas flaps may be supplied to prevent leakage around the door, and particularly at the bottom. Double doors are used on main entries at the shaft bottom, or at any point where the opening of the door causes a stoppage of the entire circulation of the mine. Such doors should be placed a sufficient distance apart to allow an entire trip of mine cars to stand between them, so that one

of the doors will always be closed while the other is open.

Stoppings.—Stoppings are used to close break-throughs that have been made through two entries, or rooms, for the purpose of maintaining the circulation as the workings advance; also to close or seal off abandoned rooms or working places. Stoppings must be air-tight and substantially built. A good form of stopping is constructed by laying up a double wall of slate, having about 8 or 10 in. of space between the two walls. This space is filled, as the building progresses, with dirt taken from the roadways, or other fine material. In the building of stoppings to seal off mine fires, it is important to begin the work at the end nearest the return air, and work toward the intake end, which should be sealed off last. This method avoids the danger of an explosion occurring within the workings that are being sealed off, as the necessary dilution of the gases within is accomplished by the fresh air-current, until the intake is finally sealed. Where the intake is sealed first an explosion is almost inevitable, as has been proved in many instances.

Air Bridges.—An air bridge is a bridge constructed for the passage of air across and over another airway, this being called an overcast; or, the crossing may be made to pass under the airway, this being called an undercast. In almost every instance, overcasts are preferable to undercasts for several reasons. An undercast is liable to be filled with water accumulating from mine drainage; it is also liable to fill with heavy damps from the mine, when the ventilation is sluggish, and to offer considerable resistance to the free passage of the air-current. An undercast can never be maintained as airtight as an overcast, on account of the continual travel through the

haulageway or passageway leading over it. This continual passing of the bridge causes a fine dust to sift into the airway and mingle with air-current. All these objections are overcome in the construction of overcast.

An air brattice is any partition erected in an airway for the purpose deflecting the current. A thin board stopping is sometimes spoken of as brattice; but the term applies more particularly to a thin board or cany partition running the length of an entry or room and dividing it into airways, so that the air will be obliged to pass up one side of the partitle and return on the other side of the partition, thus sweeping the face of heading or chamber. Such a temporary brattice is often constructed nailing brattice cloth or heavy duck canvas to upright posts set from 4 to 6 apart along one side of the entry a short distance from the rib.

Curtains.—These are sometimes called canvas doors. Heavy duck. canvas, is hung from the roof of the entry to divide the air or deflect a portion of it into another chamber or entry. Curtains are thus used very often previous to setting a permanent door frame. They are of much use in longwall work, or where there is a continued settlement of the roof, which would prevent the construction of a permanent door; also, in tempo-

rary openings where a door is not required.

HOISTING AND HAULAGE.

HOISTING.

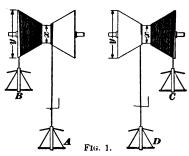
There are two general systems of hoisting in use: (a) Hoisting without There are two general systems of noisting in use: (a) Hosting without attempting to balance the load. In this system, the cage and its load are hoisted by an engine and lowered by gravity. (b) Hoisting in balance. In this system, the descending cage or a special counterbalance assists the engine to hoist the loaded ascending cage. Hoisting in balance is usually effected by the use of (1) double cylindrical drums; (2) flat ropes winding on reels; (3) conical drums; (4) the Koepe system; (5) the Whiting system:

1. Double cylindrical drums are widely used: they consist essentially of an engine coupled directly or else geared to the common axis of the drums. The drums are usually provided with friction or positive clutches and

The drums are usually provided with friction or positive clutches, and brakes, so that they can be run singly if desired, or the load can be lowered

by gravity and the brake.

Flat ropes wound on reels are sometimes used either for unbalanced hoisting with a single reel or for balanced hoisting with a double reel. With



the double reels, the load on the engine is balanced throughout the entire hoist, for, as the rope is wound on the reel, the diameter of the reel is increased, and the lever arm through which the power of the engine is applied is also increased and the mechanical efficiency of the hoisting system decreased. Thus, when the cage is at the bottom of the shaft and the entire weight of the rope is out, giving the maximum load to be hoisted. the drum is of a minimum diameter and the engine has, therefore, its greatest leverage to start the load. A flat

rope has the advantage of preventing fleeting, but its first cost, extra weight, wear, and difficulty of repairing have prevented its very general adoption.

3. Conical Drums.—A conical drum, Fig. 1, equalizes the load on an engine just as a flat rope on a reel does. On account of the fleeting of the rope, however, the drum must be set at a considerable distance from the shaft to prevent the rope leaving the head-sheave. A tail-rope gives the most perfect counterbalance, the weight of the cage and rope on each side being exactly equal.

4. In the Koope system, Fig. 2, one rope runs over and the other under driving sheaves S. A tail-rope R is used, and the head-sheaves x, x' are placed vertically and at such an

angle to each other that their grooves and the groove in the driving sheave are in line. As the main driving shaft is short, the engines can be placed close together, thus requiring a smaller foundation and engine house than for a drum hoist. The objection to the system is the liability of the rope to slipping about the driving sheave, and for

about the driving sheave, and for this reason a hoisting indicator cannot be depended on. The system is also inconvenient for hoisting from different levels in the same shaft, and, in case of the rope breaking, both cages fall to the bottom.

5. The Whiting system, Fig. 3, uses two narrow-grooved drums placed tandem instead of a single-driving sheave as is used in the Kopes system. driving sheave as is used in the Koepe system. The rope passes from the cage A over a head-sheave, under the guide sheave T and around the sheaves M. F three times, then out to the fleet sheave C, back under another guide sheave, and up over another head-sheave to the cage B. The sheave M is driven by a motor either coupled direct to its shaft, or geared. The drums F and Mare coupled together by a pair of connecting-rods like the drivers of a locomotive, and this arrangement makes it possible to utilize all the friction of both

lines, in order to change the working length of

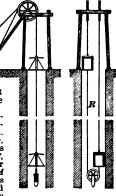


Fig. 2.

drums to drive the rope. Thus a tail-rope is not depended on to produce more friction, though one is generally used as a balance to the loads.

It is best to incline the follower sheave F from the vertical an amount

equal in its diameter to the distance between the centers of two adjacent grooves, the object being to eliminate chafing between the ropes around the drums and to prevent them from running off by enabling the rope to run from each groove in one drum straight to the proper groove in the other. This throws the shaft and crankpins out of parallel with those of the main drum, but this difficulty is overcome by the connections in the ends of the parallel rods. The fleet sheave C is arranged to travel backwards and forwards, as shown by the dotted

the rope, whereby hoisting can be done from different levels in the shaft. The power used for hoisting is generally steam for the main hoists. Electricity is, however, coming rapidly into use, particularly for smaller hoists or

and local installations, and for main hoists in locations where fuel expensive and water-power available. Gasoline engines are also being u to an increasing degree, particularly for smaller hoists and in local instal tions, and they are said to give very satisfactory results.

PROBLEMS IN HOISTING.

To Balance a Conical Drum.—Having given the diameter of one end of a conical drum, to determine the diameter of the other end that will equalize to the load on the engines. In Fig. 1, call total load at bottom A, empty case at top B, loaded cage at top C, empty cage plus rope at bottom D, small diameter of drum x, and large diameter y; then, Ax - By = Cy - Dx. Example.—In a shaft, the cage weighs 2 tons, the empty car 1 ton, the loaded car 2 tons, and the rope 2 tons. What should be the small diameter of control drum whom lored diameter x = 0.00.

a conical drum whose large diameter is 30 ft.?

$$(2+2+3)x - (2+1)30 = (2+3)30 - (2+2+1)x,$$

$$7x - 90 = 150 - 5x.$$

$$\therefore 12x = 240,$$

$$x = 20 \text{ ft.}$$

To find the Size of the Hoisting Engine.—Let D = diameter of cylinder, P = mean effective steam pressure in cylinders, r = ratio of stroke to diameter. eter of cylinder, and w = work per revolution required to be done; then, by making one cylinder capable of doing the work, n = number of strokes, u = work per minute (ft.-lb.).

$$D = 1.97 \sqrt[3]{\frac{w}{Pr}}$$
, or $D = \sqrt[3]{\frac{u}{.7854 \ Pr \, n}}$.

EXAMPLE.—What should be the size of the cylinders of a hoisting engine that is to perform 152,580 ft.-lb. of work per revolution, if the mean effective pressure is 45 lb. per sq. in. and the stroke of the piston is twice its diameter?

$$D = 1.97 \sqrt[8]{\frac{152,580}{45 \times 2}} = 23.5 \text{ in.}$$

To get up speed in a few seconds, more power than would be represented by the load to be lifted is required. Mr. Percy gives the following rule for this case: In a properly balanced winding arrangement, with uniform load, multiply the weight of coal in pounds by the average speed of the cage in feet per minute; add one-half to cover the frictional resistances, and call that the load. Then the power that must equal this must be the average effective pressure of steam in pounds per square inch on the piston, multiplied by the area of one cylinder in square inches, and multiplied again by the average speed of the piston in feet per minute.

Approximately, the average effective pressure of steam will be two-thirds

Approximately, the average effective pressure of steam will be two-thirds of the pressure shown on the gauge near the engines. A good average piston speed is 400 ft. per minute.

To Find the Actual Horsepower of an Engine for Holsting Any Load Out of a Shaft at a Given Rate of Speed—To the weight of the loaded car add the weight of the rope and cage. This will give the gross weight.

Then, H. P. =
$$\frac{\text{gross weight in lb.} \times \text{speed in ft. per minute}}{33,000}$$
; add \dagger for

contingencies, friction, etc.

EXAMPLE.—Having a shaft 600 ft. deep, gross weight of load 20,000 lb., to be hoisted in 11 minutes, what horsepower is required?

H. P.
$$=\frac{20,000\times400}{33,000}=243$$
 H. P., nearly. To which add \ddagger for contingencies, and we have 324 H. P.

In a shaft with two hoistways, use the net weight + the weight of one

The following rules regarding winding engines are given by Percy:

1. To find the Load That a Given Pair of Direct-Acting Engines Will Start.

Multiply the area of one cylinder by the average pressure of the steam per square inch in the cylinder, and twice the length of the stroke. Divide this by the circumference of the drum, and deduct ‡ for friction, etc.

EXAMPLE.—Given a pair of engines, cylinders 20 in. diameter by 40 in. stroke, the drum 12 ft. diameter, and the pressure at steam gauge 50 lb., steam cut-off at ‡, average pressure of steam in cylinder 48.2 lb.

Then, area of cylinder = 314.16 sq. in. $314.16 \times 48.2 \times 80 = 1,211,400.96$. The circumference of the drum = 452.4 in. $1,211,400.96 \div 452.4 = 2,677$.

3 of 2,677 = 1,784 lb., or the net load.

The gross load would include the weight of rope, cage, and car, but as these are balanced by the descending rope, cage, and car, the net load only is found. The drum mentioned is cylindrical.

2. Knowing the Load and the Diameter of a Cylindrical Drum, and the Length of Stroke, the Cut-off and Pressure of Steam at Steam Gauge, to Find the Area and Diameter of Cylinders of a Pair of Direct-Acting Engines.—Multiply the load by the circumference of the drum, and add one-half for friction, etc. Divide this by the mean average steam pressure, multiplied by twice the length of the stroke.

EXAMPLE.—Having the drum 10 ft. in diameter, the stroke 6 ft., the steam pressure at gauge 60 lb., the cut-off at i of stroke, and the load 5 tons, or 11,200 lb.

Then $11,200 \times 31.416$ (circumference of drum) = 351,859. 351.859 + 1 of

351,859 (or 175,930) = 527,789. The mean average pressure = 57.8 lb. $57.8 \times (6 \times 2) = 693.6$. \div 693.6 = 761 sq. in., area of piston.

761 + .7854 = 969. 1/969 = 31.13 in., or diameter of cylinder.

3 To find the Approximate Period of Winding on a Cylindrical Drum With a Pair of Direct-Acting Engines.—Assume the piston to travel at an average velocity of 400 ft. per minute, and divide this by twice the length of the stroke, and multiply by the circumference of the drum. This gives the speed of cage in Cost new invite. Divide the doubte feach by this end the result will be the feet per minute. Divide the depth of shaft by this, and the result will be the period of winding.

EXAMPLE.—Drum, 31.416 ft. circumference; stroke, 6 ft.; depth of shaft.

1,500 ft.

Then, $400 \div 12 = 33.33$. $33.33 \times 31.416 = 1,047.1$. $1,500 \div 1,047.1 = 1.43$ min., or about 1 min. 26 sec.

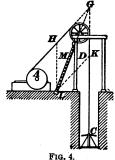
To Find the Useful Horsepower During a Winding .- Multiply the depth of shaft by net weight raised; divide this by number of minutes occupied in winding, and divide again by 33,000.

EXAMPLE.—Net weight, 2 tons = 4,480 lb.; depth, 1,500 ft.; period of wind-

ing, 1.43 minutes. Then, $4,480 \times 1,500 = 6,720,000$. $6.720.000 \div 1.43 = 4.699.301.$ 4,699,301 $\div 33,000 = 142 + H. P.$

HEAD-FRAMES.

Head-frames are built of wood or steel, and some of the typical forms are shown on pages 275 and 276. They vary in height from 30 to 100 ft., depending on local conditions.



The inclined leg of a head-frame should be placed so as to take up the resultant strain due to the load hanging down the shaft and the pull of an engine. Fig. 4 shows the graphical method of determining the direction and magnitude of this resultant force. Produce the direction of the two portions of the rope leading to the drum and down the shaft until they intersect at G, measure off a distance GK to scale to represent the load hanging down the shaft; similarly, measure off GH to the same scale to represent the pull of the engine, complete the parallelogram GHLK; the direction of the line GL represents the direction of the resultant force, and its length represents the amount of this force. The inclined leg of the head-frame should be placed as nearly as possible parallel to this resultant line, and should be designed to withstand a compressive

strain equal to this resultant.

Head-sheaves are made of iron, being sometimes entirely cast, or else the

rim and hub are cast separately and wrought-iron spokes are used. former are cheaper and quite satisfactory, but the latter are lighter and stronger, and therefore usually better. The diameter of the sheave depends on the diameter of the rope, and the table giving this will be found on page 120. The groove in the sheave should be wood-lined, to reduce wear on the rope. Wrought-iron spokes should be staggered in the hub and not placed radially.

Guides and conductors are usually of timber rigidly attached to the sides of a shaft. In England and certain parts of Europe, wire ropes are used for guides and are strongly advocated, but they have never found favor in America. These ropes when used are weighted at the bottom, and Percy gives 1 ton for each 600 ft. in depth for each wire as a good weight to be used. When not thus weighted, the ropes are fastened at the bottom and attached to levers at the top, the levers being weighted to produce the requisite tension.

Safety catches usually consist of a pair of toothed cams placed on either side of the cages and enclosing the guides. When the load is on the hoisting the cames are kept sway from the guides by suitable springs. But if

rope, these cams are kept away from the guides by suitable springs; but if the rope breaks, the springs come into action and throw the catches or dogs so that they grip the guides, and the tendency to fall increases the

grip on the guides.

Detaching hooks are devices that automatically disconnect the rope from

the cage in case of overwinding.

HAULAGE.

The magnitude of modern mines and the practice of loading or of treating the coal or ore at a large central station makes the underground haulage of the material one of the most important problems in connection with A good haulage system is now essential to make most mines a commercial success. Haulage may be considered under the following heads:

 Inclined Roads.—Gravity planes, engine planes.
 Level Roads.—Mule haulage, rope haulage (tail-rope and endless rope), motor haulage (steam, electricity, compressed air, or gasoline).

Gravity Planes.—The loaded car or trip hauls the empty car up the grade. Two ropes are attached to a drum so that the rope attached to the loaded



car unwinds from the drum as the car descends, while the rope attached to the empty Whereard and the car thus hauled up the plane. The natural slope of the ground, in a large measure, determines the grade may be lessened by constructing the incline across the slope of

the ground. The grade of the incline may be increased by carrying the upper landing forwards till a point is reached from which the required grade is obtained.

The following rule gives suggestions based on practice that has been successful: For lengths not exceeding 500 ft., the minimum grade for the incline should be 5% when the weight of the descending load is 8,000 lb. and that of the ascending load 2,800 lb. Or the inclination should not be less than 5¼ if the respective descending and ascending loads are one-half of those just given. When the length of the plane is from 500 to 2,000 ft., the grade should be increased from 5½ to 10%, according to the loads. A load of 4,000 lb. on a 10% grade 2,000 ft. long will hoist a weight of 1,400 lb.

The angle of inertia is that angle or inclination at which a car will start to move down the slope or plane. The car, when it has once started on this grade, will continue to accelerate its speed as it descends the plane AB, Fig. 5. If we decrease the angle of inclination until the plane AB occupies the position A C, such that the moving car will continue to move at a uniform velocity instead of accelerating its speed, the angle D CA will be the angle of rolling friction, and the tangent of this angle will be the coefficient of rolling friction for the car.

The upper portion of a plane is made steeper than the lower portion so that the trip may start quickly at the head and afterwards maintain auniform velocity. With a good brake to control the cars, the uniform grade of a central portion of a gravity plane should not fall much below 3°, which rresponds practically to a 5½ grade.

The acceleration f of the haulage system is given by the formula

$$f=\frac{p_1-p_2}{p_1+p_2}\times g,$$

where p_1 and p_2 are the descending and ascending pulls, respectively.

The length of steep pitch is given by the formula

$$l = \frac{v^2}{2\bar{f}},$$

where v = velocity at which the trip is desired to run.

The maximum tension or pull on the rope which may occur, if it is required to haul the loaded trip up, is

$$T = (W + wl) \sin a + (W + wl) \cos a \times \mu,$$

where W = weight of loaded trip; wl = weight of rope; a = slope angle; $\mu =$ coefficient of friction.

EXAMPLE.—Find the possible tension of a rope used to lower a loaded trip of two cars upon a plane 800 ft. long, having a uniform grade of 5% at a speed of 20 miles per hour, using a factor of safety of 10, and letting $\mu=\frac{1}{45}$, the empty cars weighing 1.000 lb. each and carrying a load of 2,000 lb. each. Assuming w=.38 lb., $T=(6,000+.39\times800)(.05+.04994)=671$ lb.

To find the number of cars that must run in a trip on a self-acting incline, use

the formula

$$N = \frac{(40 \sin a + \cos a) W_3}{(40 \sin a - \cos a) W_1 - (40 \sin a + \cos a) W_2}$$

in which N = number of cars; a = angle of inclination of plane; $W_1 =$ weight in pounds of one loaded car; $W_2 =$ weight in pounds of one empty car; $W_3 =$ weight in pounds of haulage rope; $\frac{1}{16} =$ coefficient of friction.

EXAMPLE.—A gravity plane has an inclination of 8°; it is 2,000 ft. long, the rope weighs 4,000 lb., a loaded car weighs 3,000 lb., and an empty car weighs

What number of cars must be in the trip to start it? Substituting values in the above formula, we have

$$N = \frac{(40 \times .13917 + .99027)4,000}{(40 \times .13917 - .99027)3,000 - (40 \times .13917 + .99027)1,800} = 13.6.$$

Engine Planes.—With an engine plane, the load is delivered at the foot of the plane and has to be hoisted. The engine may be either at the top or the bottom. The grade of the plane is usually uniform from top to bottom, and there may be a single track, a double track, or three rails with a turnout.

Size of Engines Required for Engine-Plane Haulage.—(a) Engine at Head of Plane, Single Track.—Calling the load on the engine or the tension of the rope at the winding drum T the weight of the ascending loaded trip W the weight of the rope per lineal foot w, and the length of the plane l, the angle of inclination or the slope angle being a, as before, we have

$$T = (W + wl) (\sin a + \mu \cos a).$$

Assume an approximate value for w, and determine T approximately. The size of rope required for this load is then obtained from the table for haulage ropes, and with this new value of w, the correct load on the engine is calculated.

Example.—What size of rope will be required to haul up an incline a loaded trip of 10 mine cars weighing 1,000 lb. each, and carrying a load of 2,000 lb. each, the inclination of the plane or the slope angle being 16° and its length 500 yd., assuming for the coefficient of friction $\mu = \frac{1}{40}$?

W = 30,000 lb., and assuming w = .89 lb., $W + w l = 30,000 + (.89 \times 1,500)$

= 31,335 lb. Sin
$$a + \frac{\cos a}{40}$$
 = .27564 + $\frac{.96126}{40}$ = .29967. Hence, $T = 31,320 \times$

.29967 = 9,394 lb. To provide against shock, we double the load or pull on the rope in calculating the size of rope required; thus, $9,394 \times 2 = 18,788$ lb., and using a factor of safety of 6, we have for the breaking strain of the rope $18,788 \times 6$

s = 57 tons. In the table of wire ropes, a $1\frac{1}{8}$ " plow-steel rope 2,000

presents a breaking strain of 56 tons. Since a $1_l''$ rope weighs 2 lb. per lineal foot, we have $W+wl=30,000+(2\times 1,500)=33,000$ lb. Then T=1

 $33,000 \times .29967 = 9,889$ lb.

(b) Engine at Head of Incline, Double Track.—The load on the engine descending the between the gravity pulls of the ascending and descending trips, including the rope, plus the friction pull of both the trips the weight of the ascending trip W_1 , we have for the difference of the gravity pulls when the loaded trip W_1 , we have for the difference of the gravity pulls when the loaded trip is at the foot of the incline, $(W-W_1+wl)$ sin a, and for the friction pull of the entire moving system $(W+W_1+wl)$ μ cos a, and $L=(W-W_1+wl)$ sin $a+(W+W_1+wl)$ μ cos a.

Assuming the same conditions as given in the example of the preceding paragraph, we have for the load L on the engine, $L = [10 \times 2.000 + 2 \times$

1,500] .27564 + $[10 \times (3,000 + 1,000) + 2 \times 1,500] \times \frac{.96126}{40} = 23,000 \times .27564$ $+43,000 \times .02403 = 7,373$ lb. instead of 9,394, the unbalanced load for single track.

(c) Engine at Foot of Incline.-The load on the engine is the same as in (a), except that the gravity pull is the pull due to the weight of the loaded cars only, the weight of the ascending rope being balanced by the descending rope, while the friction pull is increased by the friction of the descending rope. Calling the load on the engine L, as before, we have, in this case,

$$L = W \sin a + (W + 2w l) \mu \cos a.$$

Assuming the conditions of the previous example and calculating the load on the engine for this case, we have $L = 30,000 \times .27564 + [30,000 +$ $2(2 \times 1,500)$].02403 = 9,134 lb.

To Find the Horsepower of an Engine Required to Hoist a Given Load Up a Single-Track incline in a Given Time.—Multiply the length of the incline in feet by the natural sine of the angle of inclination, which will give you the vertical lift. Divide the vertical lift by the given time in minutes. Multiply this by the gross load, including weight of rope, and divide the product by 33,000.

EXAMPLE.—Length of incline, 600 ft.; angle of inclination, 35°; weight of loaded car and 600 ft. of rope, 5,000 lb.; time of hoisting, 2 minutes. Required.

the horsepower.

Sine of $35^{\circ} = .573576$. $.573576 \times 600 = 344.1456$. $344.1456 \div 2 = 172.728$. $172.728 \times 5,000 = 26 + \text{H. P.}$

33,000

Add from 25% to 50% for contingencies, friction, etc. In mine practice, 50% is not any too much to add, because the condition of track, cars, etc., is not as good, as a general rule, as on railroad planes.

To Find the Horsepower of an Engine Required to Hoist a Given Load Up a Double-Track Incline in a Given Time.—Proceed as above, using the net load, to which

should be added the weight of one rope, instead of the gross load.

ROPE HAULAGE.

The tail-rope system of haulage uses two ropes and a pair of drums on the me shaft. The main rope passes from one drum directly to the front of the loaded trip, and the tail-rope passes from the other drum to the large sheave wheel at the end of the road and back to the rear of the loaded trip. While hauling the loaded trip, the drum on which the tail-rope is wound is allowed to turn freely on its journal by throwing its clutch out, while the engine turns the other drum. When the empty trip is being hauled, the clutch on the main-rope drum is thrown out and the one on the tail-rope drum is thrown in. The engine then turns the tail-rope drum and allows the other one to pay out rope as the trip advances.

The tail-rope system is suitable for steep, circuitous, and undulating roads. The trip can be kept stretched at all points, and thus the cars will be prevented from bumping together or from being jerked apart as the trip is passing over changes in the grade. It is undoubtedly the most satisfactory system of rope haulage under the natural conditions of most haulage roads in mines, and especially so where but one road is available for haulage

purposes.

CALCULATION OF THE TENSION OF HAULING ROPE.

T = tension or pull upon rope (lb.). W = weight of loaded trip (lb.). w = weight of rope per lineal foot (lb.).

= length of two ropes; equals 2 times the distance from winding drum to tail-sheave (ft.).

d = vertical drop of rope (ft.).

= slope angle of maximum grade. $T = W(\sin a + \mu \cos a) + w(d + \mu l).$

EXAMPLE.—What size of steel wire rope will be required to haul a trip of 20 mine cars, the weight of the loaded cars being 3,000 lb. each, the depth of the shaft 300 ft., and the distance from the foot of the shaft to the tail-sheave

900 yd., the maximum grade in this haulage being 10° , $\mu=\frac{1}{45}$? Assuming a $\frac{3}{4}$ " rope, weighing .89 lb. per lineal ft.

 $T = 60,000 \left(.17365 + \frac{.9848}{40} \right) + .89 \left(300 + \frac{6,000}{40} \right) =$ say 12,300 lb., or some-

Referring to the tables for steel haulage ropes with 6 strands of 7 wires each, we find the breaking strain of a $\frac{3}{4}$ rope, weighing .89 lb. per lineal ft., is 18.6 tons, which will give a factor of safety of about 3. We would, however, use a $\frac{1}{4}$ or even a 1" rope, as a change of ropes would then be required less often. Making the necessary corrections for 1" rope weighing 1.58 lb. per lineal ft., T = 12,607 lb. what over 6 tons.

The endlass-rope system uses an endless rope, which is kept running continuously by a pair of drums geared together and set tandem. The drums are comparatively

narrow and provided with grooves for the rope to run in. drums are necessary to get sufficient friction to drive the rope when the trip is attached to it. The rope is passed around both drums a number of times, depending on the amount of friction desired. without completely encircling either. It then passes to a tension wheel at the rear of the drums and thence to the sheave wheel at the far end of the road and back to the drums. To be used to best advan-tage, this system re-

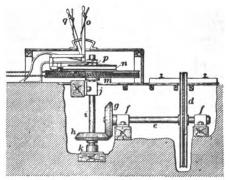


FIG. 6.

quires that the grade be in one direction and that it be necessary to haul cars from a number of places en route. The cars are attached to the rope by friction grips in a manner quite similar to the way in which street cars are attached to cable lines. It is evident, therefore, that any jerking due to the cars bumping together or stretching the hitchings would seriously injure the rope where the grip takes hold. A double road is an essential feature of endless-rope haulage.

The endless-rope system of haulage is best adapted to roads presenting a

fairly uniform grade, particularly when the trips are not spaced at fairly regular intervals along the road. Owing to delays in the delivery of the cars by the drivers and to irregularity in unloading at the tipple, it is practically impossible to have the several trips regularly spaced, and in consequence the load on the engine varies greatly. In order to take up any elongation of the rope due either to change in temperature or to stretching, some form of balance car or balance weight is used. This weight should be sufficient to keep the empty rope taut, and any tendency of the rope to slip on the winding drum may be overcome by increasing the weight in the bal-

ance car.

Then.

Fig. 6 shows a device for working a district haulage by connecting it with the main haulage. The main rope makes one or two complete turns around a the main large. The main top mass of two complete mass and the mouth of each district, and then continues on its course. This fleet wheel d is directly connected with the driving sheave m for the district by means of beveled gears g, h, as shown. The driving sheave m is thrown in or out of gear by levers o and q.

To Determine the Friction Pull on an Endless-Rope Haulige.—Let

O = output (lb. per min.);
$$w_1$$
 = weight of mine car (lb.); v = speed of winding (ft. per min.); w = weight of rope (lb.); l = length of haulage road (ft.); T = load on the rope (lb.);

 $\dot{c} = \text{capacity of mine car (lb.)};$

$$\frac{l\,0}{v}=$$
 weight of material in transit; $2\,\frac{l\,0}{v\,c}\,w_1=$ weight of moving cars, loaded and empty;

 μ = coefficient of friction.

$$\frac{lO}{v}\left(1+\frac{2w_1}{c}\right)+2wl = \text{entire moving load.}$$

And if the coefficient of friction equals 30,

$$T = \mu \left[\frac{l}{v} \left(1 + \frac{2}{c} \frac{w_1}{l} \right) + 2 w l \right];$$
H. P.
$$= \frac{\mu l}{33,000} \times \left[O\left(1 + \frac{2}{c} \frac{w_1}{l} \right) + 2 w v \right].$$

EXAMPLE.—Find the horsepower for an endless-rope system 5,000 ft. long for an output of 1,000 tons per day of 10 hours in a flat seam, the mine cars having a capacity of 2,000 lb. each and weighing 1,200 lb. each. Assuming a speed of winding of 8 miles per hour or 704 ft. per minute, and for the coefficient of friction $\mu = \frac{1}{40}$,

$$T = \frac{1}{40} \left[\frac{5,000 \times 3,333}{704} \left(1 + \frac{2 \times 1,200}{2,000} \right) + 2 \times 1.58 \times 5,000 \right] = 1,697, \text{ say 1,700 lb.}$$

$$H. P. = \frac{5,000}{40 \times 33,000} \left[3,333 \left(1 + \frac{2 \times 1,200}{2,000} \right) + 2 \times 1.58 \times 704 \right] = 36.2 \text{ H. P. or,}$$

assuming an efficiency for the engine of 60%, $\frac{36.2}{60} = 60$ H. P.

Inclined Roads.—The calculation of power for inclined roads is the same as that just given, excepting that the work due to lifting the coal through a height h must be added to that found by the previous formulas. If h equals the elevation due to the grade of the incline, the additional work of the engine due to hoisting the load from this elevation will be Oh and the total work per minute u will be

$$u = \mu l \left[O\left(1 + \frac{2w_1}{c}\right) + 2wv \right] + Oh.$$

EXAMPLE.—Assuming the same conditions as given above, and, in addition, a rise or elevation of 100 ft. in the entire length of the haulageway, we

have
$$u = \frac{5,000}{40} \left[3,333 \left(1 + \frac{2 \times 1.200}{2.000} \right) + 2 \times 1.58 \times 704 \right] + 3,333 \times 100$$

= 1,528,050 ft.-lb. per minute = 46.3 H. P., or assuming an efficiency of 60% for the engine, $\frac{46.3}{60}$ = 77 H. P.

MOTOR HAULAGE.

Locomotive Haulage. - Wire-rope haulage is very efficient in headings, on heavy grades, and against large loads, but in crooked passages it entails great costs for renewals and repairs. When the grades do not exceed 5% for short distances and average 3% against, or for short distances 8% and 5% average in favor of loads, locomotives have been found the most economical form of haulage.

The chief advantages of locomotive over rope haulage are the flexibility of the system, it being able to serve any number of side tracks in various parts of the mine, and the closeness of the source of power to the point of application. In the event of an accident due to a car jumping the track, a broken wheel, etc., it often happens that a large number of cars are piled up before the man in charge outside the mine is signaled to stop, whereas with locomotive haulage the engineer or trip rider affords immediate relief.

In high seams and under favorable conditions, steam locomotives are very economical, but there is a limit to their use, for it is not well to fire while running in the mine when using bituminous coal; hence the length of trip is practically limited to the steam furnished with one firebox of fuel. On account of their many disadvantages and of the improvements in the methods of using other forms of energy, steam locomotives are fast going out of use and are being replaced by locomotives operated by compressed air and electricity, of which a number of types have been designed in recent years, and which have been very successful and have shown a marked efficiency over the mule.

Compressed Air Haulage.—(See also page 194.) Compressed air is particularly applicable in gaseous mines, as it improves ventilation and is perfectly safe under all conditions. The great disadvantage in compressed air haulage is

the size of the locomotive.

Mr. H. K. Myers, of the Baldwin Locomotive Works, gives the following

in regard to compressed air haulage:

In order that compressed-air locomotives may be able to make a fair length of run, the tanks for storage purposes must necessarily be rather cumbersome, and constructed to carry high-storage pressures. In order that they may be designed correctly and get a minimum of storage for the maximum work expected, it is necessary to have a complete profile of the proposed haulage road, and to make a tabulated statement of the air consumption on the various grades, noting the "cut-off" necessary to produce the requisite tractive effort. By making a summation of these various amounts, and adding 20%, we will have the possible amount of air used in doing certain work as specified.

It is necessary, therefore, to provide storage on the locomotive for this amount of air at a much greater pressure than that used in the cylinders. In order that the locomotive may receive a quick charge at the stations specially provided for the purpose, it is necessary to have stationary storage of adequate pressure and capacity for the purpose.

At the present time, it is the custom to compress for the stationary storage to 800 lb., and to have the volume of this storage at least double the tank capacity of the locomotives comprising the system. This allows an equalized pressure in the locomotive storage of approximately 600 lb.

The following formula is useful in determining the capacity of stationary

storage: $P' = \frac{pV + PX}{V + X}$; in which V = volume of storage on locomotive;

X = volume of stationary storage desired; p = cylinder pressure; P = stationary storage pressure; and P = locomotive storage pressure. If the average time for each trip is 30 minutes, the compressor must be

able to compress in that time to pressure P, the calculated amount of air required for one trip or series of trips for the various locomotives included in the haulage. In general, it is customary to extend extra-strong pipe into the mine and of such length and diameter as to have the required volume for the stationary storage. There are times however when it would be found more economical to arrange for tank storage either inside or outside the mine, but in general, especially when the mine is advancing, it is the better practice to install pipe storage since it increases the range of the locomotive as the workings advance.

The following table gives the various tractive efforts of different sizes of compressed-air locomotives, when working at 100 lb. cylinder pressure, and various cut-offs. If other pressures or strokes are used, the tractive efforts are directly proportionate. This table is calculated by means of the formula,

tractive effort =
$$\frac{d^2 l x p}{D}$$
;

in which d = diameter of cylinder; D = diameter of driver; l = length ofstroke; p = working pressure of the cylinders; and x = variable due to thevarious cut-offs.

TRACTIVE EFFORTS OF COMPRESSED-AIR LOCOMOTIVES.

		Cylinder. Diam- eter of on Driver. Driver.		Tractive Effort for Each 100-Lb. Cylinder Pressure at Various Cut-Offs.						
Diam. Inches.	Stroke. Inches.		Pounds	7	ŧ	ł	1	ł	‡	ł
5 6	10 10	24 24 26	6,000 8,500 13,000	1,020 1,470 2,200	990 1,425 2,150	920 1,320 1,990	835 1,200 1,810	710 1,020 1,540	530 760 1.140	325 445 700
7 8 9 10	12 12 14 14	26 26 26 26	18,000 18,000 25,000 32,000	2,880 4,340 5,280	2,750 4,140 5,150	2,600 3,840 4,740	2,360 3,490 4,310	2,000 2,960 3,660	1,510 2,220 2,630	900 1,350 1,670
11 12	16 16	28 28 28	42,000 52,000	6,770 8,050	6,450 7,800	5,980 7,200	5,440 6,550	4,620 5,580	3,470 4,150	2,140 2,550

On account of certain losses due to radiation, etc. for cut-off at full length of stroke in steam practice, x is taken as .85. While cylinder surface acts as a detriment to the use of steam, it acts entirely opposite in the use of air, for the reason that, in the expansion of the air, very low temperatures are produced, and, with a maximum of cylinder surface exposed, we absorb a maximum of heat from the surrounding air, which virtually adds new energy to the air, thus acting as a reheater. Therefore in air practice, x is made .98 for full-stroke cut-off, with the others proportionately high. simple-expansion cylinders are used, the working pressure should not exceed 130 lb., while, with compounds, one can easily use from 180 to Where it is imperative to have a minimum-225 lb. with great economy. sized locomotive storage with a maximum run, this can be accomplished with compound locomotives. Originally, it was the custom to lag the cylinders as in steam practice, but now it is found advantageous to leave them bare and to corrugate both sides and ends so as to present a maximum surface to the surrounding atmosphere while running, thus absorbing new energy.

EXAMPLE.—It is desired to haul trips of 60 cars, empties weighing 2,000 lb. and loads 6,000 lb. each, over a track having the following profile, and with one charge of air. All grades are in favor of loads. (The following calculations have been made with the slide rule.)

PROFILE OF ROAD.

	Grade.	Distance.	Grade.	Distance.	Grade.	Distance.
•	1.3%	800 ft.	0.30%	700 ft.	2.4%	400 ft.
	2.0%	600 ft.	1.77%	1,025 ft.	3.5%	425 ft.
	1.3%	800 ft.	0.90%	300 ft.	1.2%	320 ft.

The maximum grade being 3.5%, and the car friction in this case being 1.8, the total resistance when ascending a 3.5% grade due to cars is, hence, 3.5% $\pm 1.4\%=4.5\%$. Since it is desired to haul 60-car trips, and all grades are in favor of loads, it is only necessary to provide a locomotive capable of hauling 60 empties weighing 120.000 lb. up the above-mentioned grade. The drawbar pull necessary to do this is 4.5% of 120.000 lb. = 5.400 lb. In general, it will require a locomotive having a weight on drivers of 5 times the tractive effort desired if steel tires are used, as is the practice in the construction of air locomotives, and 6 times the tractive effort if cast-iron chilled wheels are used, as is the practice in electric locomotives. We will therefore assume the necessary weight of the locomotive to give the proper adhesion as 32,000 lb., and we calculate that the tractive effort necessary baul itself up the 3.5% grade would be 3.5% \pm .5% \pm 4% (.5% covering the friction of the locomotive on the level) of 32,000 lb., or 1,280 lb., to which we add the necessary drawbar pull to haul the desired load, 1,280 +5.400, and have a total tractive effort of 6,680, which is about the limit of a locomotive only rail with sand.

By consulting the table of tractive efforts of compressed-air locomotives, we see that, at 100 lb. working pressure, a $10'' \times 14''$, 26'' driver locomotive has a maximum tractive effort at $\frac{1}{4}$ cut-off, which is practically full stroke, of 5,280 lb., and by dividing this into our necessary tractive effort, we find that the necessary working pressure would be about 130 lb.

On this basis, we then make up the following table in order to ascertain the necessary tractive representation:

the necessary air consumption:

		Going in	With Emp	TIES.	
Grade.	Distance.	T. E.	Strokes.	Cut-Off.	Cu. In. Air Used.
1.3	800′	3,375	120	¥	126,000
2.0	600′	4,450	80	i	176,000
1.3	800′	3,375	120	ł	126,000
0.3	700′	1,830	105	i	55,125
1.77	1,025'	4,100	150	I I	315,000
0.9	300′	2,750	40	Į.	42,000
2.4	400′	5,075	60	i i	157,500
3.5	425'	6.760	65	į	239,000
1.2	320′	2,220	50	ł	52,500
		Coming (OUT LOADI	ED.*	
0.3	700′	2,600	105	1	110,000
					1.399.125
20% ad	lditional				279,825
To	tal				1,678,950 cu. in.

This equals 975 cu. ft. at 130 lb. pressure used in hauling the required loads on a single round trip. Since we should return to the starting point with 130 lb. in the locomotive storage, it is evident that the volume of the tanks shall allow for the use of 975 cu. ft. in addition to 1 volume at 130 lb.

Let V = volume of storage on locomotive; P' = pressure of storage on locomotive; P = working pressure; P' = volume at working pressure necessary to do the work required.Then the product of the volume of the locomotive storage by its pressure must equal the sum of the volume necessary to do the work required multiplied by the working pressure, and the locomotive storage volume by the working pressure, thus.

the working pressure, thus,

$$P'V = pV + pV', \text{ or, } V = V'\frac{p}{P'-p}.$$
 If $P' = 650$, then $V = 975 \times \frac{130}{650-130} = 244$ cu. ft.

With one locomotive, making trips every 30 minutes, we must arrange for a compressor capable of compressing 975 cu. ft. at 130 lb. in this time. Since it is customary to rate compressors at their capacity in free air per minute,

the above is equivalent to $\frac{975 \times 130}{14.7 \times 30}$ = 288 cu. ft. free air per minute.

This must be compressed to 800 lb. in the compressor, and stored in stationary storage. If X is the volume of the stationary storage,

$$P = \frac{pV + PX}{V + X}.$$

$$X = V \frac{P' - P}{P - P'} \text{ or } X = 244 \times \frac{650 - 130}{810 - 650} = 846 \text{ cu. ft.}$$

The length of the haulage is 5,370 ft., hence the cross-section of the pipe necessary to furnish the requisite storage is $\frac{846}{5.370}$ = .157 sq. ft.

From the following table, this would require a 54" pipe, but for practical purposes it is possible that a 5" pipe would be selected.

^{*} Returning with loads, it is possible that there is only one grade that the trip will have to be hauled.

STANDARD STEAM AND EXTRA-STRONG PIPE USED FOR COMPRESSED-AIR
HAULAGE PLANTS.

Trade Diam-	Cu. Ft. in	Lineal Ft. Necessary	Ste	am.	Extra	Strong.	Trade Diam-
eter. In.	1 Lineal Ft.	to Make 1 Cu. Ft.	Thick- ness.	Weight per Ft.	Thick- ness.	Weight per Ft.	eter. In.
2 2½ 3 3½ 4 4½ 5 56	.0218 .0341 .0491 .0668 .0873 .1105 .1364 .1650	45.41 29.32 20.36 15.00 11.52 9.05 7.33 6.06 5.10	.15 .20 .21 .22 .23 .24 .25 .26	3.61 5.74 7.54 9.00 10.70 12.30 14.50 16.40 18.80	.22 .28 .30 .32 .34 .35 .37 .40	5.02 7.67 10.20 12.50 15.00 17.60 20.50 24.50 28.60	2 2 4 3 3 4 4 4 4 5 5 4 6

From the following table we see that it would require $2.88\times32.5=93.6$ H. P.; hence, we would be compelled to arrange for a boiler capacity of practically 100 H. P., provided we used a three-stage compressor, as is the general custom.

HORSEPOWER NECESSARY TO COMPRESS 100 CU. FT. OF FREE AIR TO VARIOUS PRESSURES AND WITH TWO-, THREE-, AND FOUR-STAGE COMPRESSORS.

Gauge	Horse	ower Nec	essary.	<i>a</i>	Horsepower Necessary.			
Pres- sure.	Two- Stage.	Three- Stage.	Four- Stage.	Gauge Pressure.			Four- Stage.	
100 200 300 400 500 600 700 800	15.7 21.2 24.5 27.7 29.4 31.6 33.4 34.9	15.2 20.3 23.1 25.9 27.7 29.5 31.2 32.5	14.2 18.8 21.8 24.0 25.9 27.4 28.9 30.1	900 1,000 1,200 1,400 1,600 1,800 2,000 2,500	36.3 37.8 39.7 41.3 43.0 44.5 45.4	33.7 34.9 36.5 37.9 39.4 40.5 41.6 43.0	31.0 31.8 33.4 34.5 • 35.6 36.7 37.8 39.0	

Electric Haulage.—Mr. H. K. Myers says in regard to mine haulage by electricity: In general, it costs from 6 to 10 cents per ton to deliver coal from face of workings to shaft, slope, or tipple, where the haul is 1 mile and the tracks approximately level; yet I know three mines that at present haul from parting with the trolley system, the miner delivering from face of room, making an average round trip of 9,000 ft., at a total cost of 1 cent per ton. These mines have never had a mule in them, and it would be almost an impossibility to introduce them, for the reason that the seam is of such thickness that the clearance between the and roof is only about 4 ft. Since the advent of the electric-mining locomotive, there has been a change in the mine wagons universally used. Formerly it was customary to find as much as 60 lb. per ton car resistance on the level, while at present it is as low as 15 lb.

In dimensioning mining locomotives, it is customary to make the weight from 6 to 8 times the necessary tractive effort, dependent entirely on the nature of the work. If the work is constant and a maximum, then the weight will be only 6 times the torque of the motors, while if the work is intermittent with a short-time maximum tractive effort, then the factor will be 8. The weight of an electric locomotive running at a speed of 6 to

8 miles per hour with intermittent load may also be expressed on a basis of 400 lb. for each rated horsepower of the motor, and the weight should be 8 times the rated drawbar pull, regardless of speed. For continuous work, these weights should be decreased 25%.

DRAWBAR PULL ON VARIOUS GRADES FOR DIFFERENT SIZED LOCOMOTIVES.

Waight	Grades.							
weight.	Level.	1%	2%	3%	4%	5*	6%	
4,000	500	460	420	380	340	300	260	
							520 780	
							1,300	
28,000	3,500	3,220	2,940	2,660	2,380	2,100	1,820	
40,000	5,000	4,600	4,200	3,800	3,400	3,000	2,600	
	8,000 12,000 20,000 28,000	4,000 500 8,000 1,000 12,000 1,500 20,000 2,500 28,000 3,500	4,000 500 460 8,000 1,000 920 12,000 1,500 1,390 20,000 2,500 2,300 28,000 3,500 3,220	Level. 1% 2% 4,000 500 460 420 8,000 1,000 920 840 12,000 1,500 1,380 1,260 20,000 2,500 2,300 2,100 28,000 3,500 3,220 2,940	Weight. Level. 1% 2% 3% 4,000 500 460 420 380 8,000 1,000 920 840 760 12,000 1,500 1,380 1,260 1,140 20,000 2,500 2,300 2,100 1,900 28,000 3,500 3,220 2,940 2,660	Weight. Level. 1≴ 2≴ 3⅓ 4⅓ 4,000 500 460 420 380 340 8,000 1,000 920 840 760 680 12,000 1,500 1,380 1,260 1,140 1,020 20,000 2,500 2,300 2,100 1,900 1,700 28,000 3,520 2,940 2,660 2,380	Weight. Level. 1% 2% 3% 4% 5% 4,000 500 460 420 380 340 300 8,000 1,000 920 840 760 680 600 12,000 1,500 1,380 1,260 1,140 1,020 900 20,000 2,500 2,300 2,100 1,900 1,700 1,500 28,000 3,500 3,220 2,940 2,660 2,380 2,100	

In mines it is found that the friction between wheel and rail is less than on the surface, due to dampness and powdered coal on the rail. The tractive efforts with chilled wheels is usually considered 1 of the weight. The table on page 408 and diagram on page 409 give hauling capacities of

locomotives in tons of 2.000 lb.

For maximum continuous work, it is necessary to have a grade such that the efforts to haul the same number of empty wagons as loaded are equal. With the car resistance considered 14 and the loaded cars weighing 3 times as much as the empties, this is found to be 1 of 1%. The most critical point in the designing of mining locomotives is to make the limiting dimensions a minimum. The demands for various dimensions are wonderful. The headings in mines are never of more generous proportions than really necessary, and all clearances a minimum. The minimum dimensions for mining locomotives are as small as 2 ft. for wheel base, 8 ft. for length over all, and 3 ft. width. Scarcely two orders carry the same dimensions, and it is impossible to have any kind of a standard. In consequence of this, it is necessary to have a great variety of motors suitable for gauges as narrow as 18 in. and for wheels as small as 20 in. in diameter. With such a variety, it becomes possible to construct a locomotive weighing 40,000 lb. on 3' gauge, having the width over all 62 in., height 35 in., and length 12 ft. In construction, it is necessary to have the most modern form of motors and the most rigid mechanical construction.

The motors now used are of the best possible construction and efficiency. They are of the slow-speed street-car type, 6 to 8 miles per hour winding, and range in size from 4 to 50 H. P. It is customary to use the rheostatic type of controller for mining locomotives, on account of its small dimensions and apparent efficiency for this class of work, but it is doubtless but a short time until a very compact form of series-parallel type will be devised. On account of the use of this rheostatic controller, it becomes necessary to provide for large diverter capacity, and since the locomotive is designed for the maximum tractive effort, it is hardly ever possible to run without resistance and, hence, a large amount of current must be dispersed with the consequent heating. If the motors are overloaded, they heat rapidly, this heating varying as the square of the current. A motor that has a rating of 40 amperes for regular work, if worked for 3 minutes at 100 amperes, should not be subjected to such a strain oftener than once in 184 minutes, as shown

by the following equation:

 $40^{\circ} \times x = 3 \times 100^{\circ}$; x = 18 minutes.

Using the same problem given under compressed-air locomotives, in which the maximum tractive effort was 6,760 lb., we find from the table of drawbar pulls that a locomotive equipped with two 50 H. P. motors (equals 100 H. P.) will carry the load with an overload, these motors being rated for continuous work at approximately 32 amperes of 500 volts.

Using the formula $\sqrt{\frac{\sum ia^2}{T}} = 64$, in which t = various times at which

various amounts a of current are used on the corresponding grades, z summation of the items t a^2 calculated for each section or grade, and z total time that should be taken for each trip, we calculate the following table:

Grade.	Dist.	T. E.	Time. Minutes.	Amperes.	t a?
					Empties.
1.30	800	3,375	1.5	114	19,600
2.00	600	4,450	1.1	134	19,900
1.30	800	3,375	1.5	114	19,600
.30	700	1.830	1.3	74	7,100
1.77	1.025	4,100	2.0	128	32,800
.90	300	2,750	.6	100	6,000
2.40	400	5,075	.8	148	17,300
3.50	425	6,760	.8	182	26,500
1.20	320	2,220	.6	86	4,400
		, -,			Loads.
.30	700	2,600	1.3	96	13,900
				<u>-</u>	$167.100 = \sum t a^{t}$

$$\sqrt{\frac{167,100}{T}}$$
 = 64; 4,096 T = 167,100; T = 40.

By this means we can make 60-car trips every 40 minutes without injury to the motors, based upon a speed of 6 miles per hour. (See also page 215.) Speed of haulage depends on the system of haulage used and on the condition of the haulage road. The law in Pennsylvania provides for a speed of haulage not over 6 miles per hour, and this is the speed at which electric and

HAULING CAPACITY OF ELECTRIC LOCOMOTIVES.

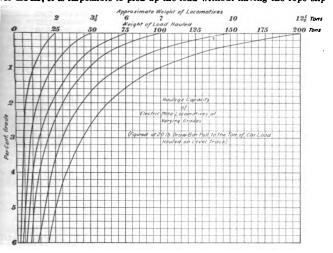
ower.	bt.	r Pull	nal Car nce per Level.					G	rade	28.				
Horsepower.	Weight.	Drawbar Pull on Level.	Frictional (Resistance Ton on Lev	Level.	號	1%	11%	2%	21%	3%	31%	4%	5%	6%
10	4,000	500	20 30 40	23 15 12	15 11 9	10 8.4 7	8 6.7 5.7	6.3 5.4 4.7	5.2 4.5 4.0	4.2 3.8 3.4	3.5 3.2 3.0	3.0 2.7 2.5	2.2 2.0 1.8	1.6 1.5 1.4
20	8,000	1,000	20 30 40	46 31 23	29 22 18	21 17 14	16 13 11	13 11 9.5	10.3 9 8	8.4 7.5 6.8	6.4	6.0 5.4 5.0	4.0	3.0
30	12,000	1,500	20 30 40	69 43 34	44 33 26	32 25 21	24 20 17	19 16 14	15 13 12	13 11 10	10.7 9.6 8.8	9.0 8.2 7.5	6.5 6.0 5.6	4.4
5 0	20,000	2,500	20 30 40	115 77 58	55	52 42 35	40 33 29	32 27 24	26 22 20	21 19 17	18 16 15	15 14 13	11 10 9.3	7.9 7.3 6.8
7 0	28,000	3,500	20 30 40	161 107 81	103 77 61	74 59 50	56 47 40	44 38 33	36 31 28	30 26 24	25 22 20	21 19 18	15 14 13	11 10 9.6
100	40,000	5,000	20 30 40	230 153 115	110	105 84 70	80 67 57	63 54 47	52 45 40	42 38 34	36 32 29	30 27 25	22 20 19	16 15 14

appressed-air haulages are usually calculated and at which loaded trips usually run. Empty trips are usually run at a slightly higher speed. The speed for tail-rope haulage is given by three prominent makers of

th plants, as follows: (a) 600 to 700 ft. per minute; (b) 8 to 10 miles per

 \mathbf{vur} ; (c) 6 to 8 miles per hour.

The speed for endless-rope haulage is given by the same makers as (a) 10 to 150 ft. per minute; (b) 1 to 2 miles per hour; (c) 150 to 200 ft. per funute. A slow speed for endless rope is to be preferred as being much core economical in the wear of the rope and cars, and many prefer a singlear system to a trip system, thus doing away with the trip rider. By handing the cars singly or even in trains of two and at a slow speed, the load an be picked up without any slippage of the rope through the grips; while f trains of from 12 to 25 cars are used with the rope traveling 3 to 34 miles ser hour, it is impossible to pick up the load without having the rope slip



through the grip, thus heating the rope and cutting it. The slow-speed, single-car or small-train, system requires more cars, but this is counterbalanced by the life of the cars and rope. Those that have tried both systems

prefer the slow-speed small trip to the high-speed large trip.

It has been found in general practice that the maximum pulling power of a mule as well as a locomotive is, approximately, one-fifth its weight, or, in other words, a locomotive will pull as much as the same weight of mules

will pull, and at a speed about three times as great.

Cost of Haulage.—So much depends on local considerations that it is difficult to give costs of haulage that will be of service. Mule haulage has been given as costing under different conditions, 5.74 cents and 7.15 cents. cents per ton-mile, and in other locations 2.35 cents, 2.95 cents, and 7.15 cents

per ton of coal hauled.

The Berwind-White Coal Mining Co., at Windber, Pa., uses 30 electric locomotives at various mines, which average, approximately, 400 tons per day of 9 hours, per locomotive, over an average haul of 2 miles for the round trip. The approximate cost for operating one of these locomotives, including the wages of motorman, trip rider, and proportion of power-house expense, is about \$6.00 per day, or 1½ cents per ton of coal haul per mile. If the total load, including weight of cars, is considered, it figures ? of 1 cent per ton per mile. These figures do not, however, include grades, which is an important factor in equating costs per ton per mile. In these mines there are no mules

whatever, the locomotives distributing the empty cars to room partings, in the men to push to the face. If the haul is done between side tracks as under similar grade conditions, the same locomotives could easily hand

1,000 to 1,200 cars per day.

Mr. F. J. Platt, of Scranton, Pa., gives the following comparative costs electric and mule haulage per ton of coal hauled and under approximate the same conditions in the same mine:

Name of Mine.	Mule Haulage. Cents.	Electric Haulage Cents.
Green Ridge Colliery New York & Scranton Coal Co New York & Scranton Coal Co. Mt. Pleasant Colliery Hillside Coal & Iron Co. Hillside Coal & Iron Co.	7.15 6.58 2.35 2.95 10.77 9.10	2.76 2.62 1.07 1.27 4.56 4.65

The following costs of electric haulage, per tou of material hauled, are given in the catalogue of the General Electric Co.:

Name of Mine.	Mule Haulage. Cents.	Electric Haulage. Cents.		
Wythe Lead & Zinc Co Blossburg Coal Co. Cleveland-Cliffs Iron Co. ('94, '95, '96)	10	2.56 7.9 3.9, 4.5, 4.8		

At Carbondale, Pa., compressed-air locomotives have hauled coal for 1.5 cents per ton-mile, at Mill Creek, Pa., for 3.77 cents per ton-mile, and at Glen Lyon, Pa., for 1.89 to 1.93 cents per ton-mile.

MINE ROADS AND TRACKS.

Underground or mine-car tracks should be solidly laid on good sills, resing on the solid floor of the mine. They should be well ballasted, and should have good clean gutters on the lower side of the entry, so that the rails may be protected as much as possible from the action of the mine water. Much of the following data, on mine roads is based on an article on "Mine Roads," by Mr. H. L. Auchmuty, "Mines and Minerals," March 1900.

Grade.—The grades depend entirely on circumstances, but, when possible, the grade should be in favor of the load, and should be at least 5 in. in 100 ft. to insure flow in the gutters alongside the track. On main roads, where wagons having a capacity of 1.5 to 2.5 tons are hauled by animal power, the grades should not exceed 1% to 2% in favor of the loaded wagon. Such a rate grades should not exceed 15 to 25 in layor of the loaded wagon. Such a rate of grade provides for an easy return haul of the empty trip without wearing out the stock, and likewise insures good drainage. With grades under 16, unless the ditches are kept perfectly clean, the drainage is apt to be sluggish, and then, in low places, we are sure to find a wet and muddy track, which is a great source of waste energy.

Where hauling is done by locomotives, whether by compressed air of steam, the adverse grades should not be over 1.5% to 2.5% if it can possibly be exceeded. When gradients are heavy to great a percentage of the treefive

avoided. When gradients are heavy, too great a percentage of the tractive power of the locomotive is consumed in drawing itself up the grade.

Ties should be spaced about 2 ft. apart, center to center, making 15 to a rail. The rail should be well spiked to the ties with four spikes to each tie, the joint between two rails on one side of the track being located about midway between two joints on the opposite rail. Care should be taken in locating the spikes that they are not all in the center of the tie, thereby Asing a tendency to split the same. It is best to place them each side of center with two spikes between the rails, on one side, and the two spikes the outside of the rail on the other side of the center of the tie. With the akses so located, there is no tendency for the tie to slide, as there is fan atside and inside spike are on the same side of the center of the tie. Ties a ving a 5 in. face and 4 in. deep by 5\frac{1}{2} ft. in length should be used for the redinary sizes of rail, i. e., 16 lb. to 20 lb., and, in general, the thickness rould be sufficiently great that the spike does not pass entirely through the e, as then its holding power is greatly diminished. On haulage tracks there 35-lb. to 40-lb. rail is used, the ties should be at least 5 in. deep and ave a face of 6 in., the ties ordinarily used for lighter sizes of rails being nitirely too thin for rails of this weight, as a larger spike than the ordinary in. x \(\frac{1}{2}\) in is required to securely hold the rails to place. The ends of the lease distance from the rail, and, with each the placed at right angles to the rail as it should be, we have a well-spaced, neat-looking track, which, when well tamped with the ballast, is perfectly solid. On curves, the ties hould be laid so as to form radii of the curves of the track.

Rails.—The weight of rail to be chosen in any individual case depends entirely on the weight of wagons used, and the motive power. For wagons whose capacity is about 1.5 tons, the weight of rail, when the motive power is tive stock, should not be less than 16 lb. per yd., while for wagons having a capacity of 2 tons or over, a 20-lb. rail should be used. There is no economy in using a very light rail, as the base is gradually eaten away by the mine water when it comes in contact with the metal, and in the case of a heavy section of rail, it will be much longer before the rail becomes weakened.

On main roads, where haulage machinery of one kind or another is used, the weight of rail for 2-ton wagons should be from 25 lb. to 35 lb. per yd.,

and on steep slopes as high as 40 lb. per yd.

In the case of locomotive haulage, authorities claim that the weight of rail should be regulated by allowing 1 ton for each driver for each 10 lb. weight

of rail per yd.

Gauga.—The gauge of the track in coal mines should not be less than 30 in. nor more than 48 in. A mean between these two, or a gauge of from 38 in. to 42 in. is desirable, because it combines, to a certain extent, the advantages claimed for the extremes. The advocates of broad gauges believe that the greater stability of the track and the consequent reduction in haulage expenses, the increased capacity of the broad-gauged mine cars, the reduction in the outlay for rolling stock, and for repairs to the same, more than equal the disadvantages of broad as compared to the narrow gauges.

Advocates of the narrow gauges think that the ease of hauling around sharp curves, the reduction in cost of construction, and the use of mine cars with inside wheels, are advantages greater than those advanced by the advocates of the broad gauges. An allowance of about \$\frac{1}{2}\$ in. should always be made between the wheel gauge and the track gauge. By so doing, the resistance to hauling is greatly overcome, and there is no binding of the wagons on the track, hence a less likelihood of having derailed wagons. With an average running wagon, there is a resistance of 15 to 20 lb. per ton tractive force on a level track, which would be equal to the resistance occasioned by a grade of .75\$/ to 1\$\frac{1}{2}\$, and with wagons that bind on the track, this resistance is greatly increased.

Euros should be of as large a radius as possible, and never, if possible, of less radius than 25 ft. The resistance of curves is very considerable. The less the radius of the curve, and the greater the length of the curved track occupied by the trip, or train, the greater the resistance. The length of wheel bases of the cars, the condition of rolling stock and of the track, and the rate of speed, all influence the resistance, and there is no formula that will apply to all cases. In practice on surface railroads, engineers compensate for curves on grades at the rate of $\frac{1}{120}$ ft. in each hundred feet for each degree of curvature, the grade being stated in feet per hundred. In mine work, this compensation is not made, as the gain will not pay for the labor that must necessarily be employed to do work in a thoroughly scientific manner.

Sharper curves can be used on narrow-gauge roads than on broad-gauge roads, because the difference in length of the inner and outer rails on curves on the same degree is not quite so great, and also because the wheel bases of cars are less. The track should be spread about ! in. on easy curves, and

on very short curves about 1 in., or as much as the tread of the wheels permit. A good rule is to widen the track in for each 210 of curvat Short and irregular curves are to be avoided whenever possible, as increase the load and are destructive to rails and rolling stock. Whenasi curve is necessary, the rail should be bent to the right curvature by portable rail bender, or by a jack and clamps.

To Bend Rails to Proper Arc for Any Radius.—Rails are usually 30 ft. long, at the most convenient chord to use in bending mine rails is 10 ft.

Then, having the radius and chord, we find the rise of middle ordinate squaring the radius, and from it take i the square of the chord. Extract square root of the remainder and subtract it from the radius; the result was the rise of the middle ordinate. Thus, having a radius of 30 ft. and chord of 10 ft., the middle ordinate will be

$$30 - \sqrt{30^2 - 5^2}$$
, or 0.42 ft.

Rail Elevation. - In elevating rails on curves, consider whether the hauling is to be done by a rope, or by a locomotive, or electric motor. For either of the latter, elevate the rail on the outside of the curve; but for the first elevate the inner rail, since as the power is applied by a long flexible rope, there is always a tendency for both rope and wagons to take the long chord of the curve as soon as the point of curve is reached. On slope hallages, operated by a single rope, when the weight of the wagons traveling on the grade of the slope is sufficient to draw the rope off the hoisting drum, the rails on curves should be elevated on the outside, the effect then being similar to that of a locomotive, i. e., the centrifugal force tends to throw the wagon to the outside of the track. In such cases, the elevation should be moderate so as not to interfere with the trip when drawn out again by the rope—the opposite effect being then experienced. On an 18° curve (319 ft. radius), an elevation of 2 in. or 3 in. in the outer rail, where the haulage was by slope rope, has never given any trouble in operating. In general, the elevation of rail necessary for different degrees of curvature for a 42" track gauge should be made in accordance with the following table:

TABLE OF ELEVATIONS.

For outer rail of curves for a speed of 10 to 15 miles per hour and a gauge of track of 42 in. for locomotives; or for slope haulages where cars run down grade by gravity.

•	Degree	Radius	Elevation	Degree	Radius	Elevation
	of	of	of Outer	of	of	of Outer
	Curve.	Curve (Ft.).	Rail (In.).	Curve.	Curve (Ft.).	Rail (In.).
-	1 2 3 4 5 6 7 8	5,729.6 2,864.9 1,910.1 1,432.7 1,146.3 955.4 819.0 716.8 637.3	-ie-ie-ie-ie-ie-ie-ie-ie-ie-ie-ie-ie-ie-	10.0 12.0 15.0 18.0 20.0 57.3 95.5 114.6	573.7 478.3 383.1 319.6 287.9 100.0 60.0 50.0	1

No elevation should be over 41 in., which would be equivalent to an elevation of 6 in. for standard track gauge of 4 ft. 9 in., the latter being considered as the maximum for standard gauge.

Rollers.—The rollers on level tracks should not be more than about 20 ft. apart to properly carry the rope, and on gravity slopes where the lower end of the slope gradually flattens off, the distance between rollers should not be more than 12 to 15 ft., as this spacing allows the trip of wagons to run much farther, by keeping the rope well off the ties, than if they are farther apart, thereby not supporting the rope, and causing a great amount of friction between the rope and the ties. With tracks in fair shape and rollers 12 to 15 ft. apart, the resistance, due to the rope in running empty wagons down grades varying from 3.84 to 6.24, varied from 64 to 154 of the weight of ropes by actual trial.

thes.—The switch, or latch, most commonly used in mines is shown Tig. 7. When the branch or siding is in constant use, an ordinary railway is substituted for the bar b. The latches a, a are wedge-shaped bars of In (made as high as the rail) with an eye in the thick end.

Fig. 7.

sometimes connected together by a rod attached to a lever so that they may both be moved at once from the side of the track, or by a person situated some distance away. This switch is made selfclosing or automatic whenever it is necessary to run all the cars off at the branch (the switch then being used only to admit cars to the main track) by attaching the latches through a bar or lever to a metallic spring, a stick of some elastic wood, or a counter weight, to pull them back into a certain position whenever they have been pushed to one

side or the other by the passage of a car the main track. Figs. 10, 11, 12, and 13 show some of the applications of

ese spring latches or automatic switches.

A modification of this switch is shown in Fig. 8, which represents a form Chouble switch. These latches are set by the drivers, who kick them over and drop a small square of plate iron between them to hold them in place his switch costs more than the other style and is better adapted to outside oads than to inside roads.

The ordinary movable rail switch in common use on all surface railways sometimes used in mine roads. It is commonly used in slopes arranged as

shown by Fig. 12, to replace latches set by the car, and is also largely used in outside roads.

For crossings, ordinary railway frogs and grade crossings are sometimes used, as is also a small turntable, which then answers two purposes. More frequently the plan shown in Fig. 9, in which four movable bars are thrown across the main track whenever the other road is to be used, is adopted.

The subordinate road is built from 11 to 2 in. higher than the main road, to allow the

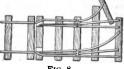
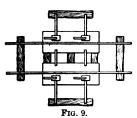


FIG. 8.

bars to clear the main-track rails. Turnouts.—On gangways or headings used as main haulage roads, turnouts should be constructed at convenient intervals to allow the loaded and empty trips to pass. These turnouts should be long enough to accommodate from 5 or 6 up to 15 or 20 cars. The switches at each end may be made self-acting so that the empty trip, coming in, is thrown on the turnout, and in running out on the main track at the other end, the loaded cars open the switch, which immediately closes.

As there is constant trouble with self-setting switches, either from small



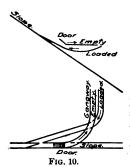
fragments of coal or slate clogging them up, or from insufficient power of the spring to move them, they are viewed with disfavor by many mine managers, who do not care to use them under any conditions. Slope Bottoms.—At the foot of a slope,

or at the landing on any lift, the gang-way is widened out to accommodate at least two tracks—one for the empty and one for the loaded cars. The empty track should be on the upper side of the gangway, or that side nearer the floor of the seam, and the loaded track on that side of the gangway nearer the roof of the seam.

An arrangement of tracks often used

is shown in Fig. 10. At a distance of 40 or 50 ft. above the gangway, the slope is widened out to accommodate the branch leading into the gangway loaded track. This branch descends with a gradually lessening inclination until nearly at the level of the gangway it turns into the main loaded track. A short distance above the gangway.

a bridge or door is placed, which, when closed, forms a latch by which the empty cars are taken off the slope. The empty track is about 6 ft. high than the loaded track, and is carried over it on a trestle. The illustration i Fig. 10 shows the plan as arranged for a single slope, or one side only of slope taking the coal from both direction



When coal is being raised from this lift the bridge is closed; the empty car come down and is run off over the bridge; the car is unhooked from the rope, and the chain and hook attached to the rope ar thrown down to the branch below or which a loaded car is standing; the loaded car is attached, the signal given, the car ascends to the main track on the slope, opening the switch—or the switch may be set each time by the bottom men, by a lever at the bottom of the branch. This plan can only be economically applied in thick seams, as the height necessary to allow one track to cross the other on a trestle cannot be obtained in seams of moderate thickness without taking down a large amount of top.

A more simple plan, which dispenses with the bridge, is often used. The branch is laid off, as shown by Fig. 10, but, near

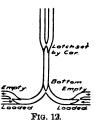
the point where it enters the gangway, a switch opening into the empty track is placed. By this arrangement, the tracks cannot be as well arranged for handling the cars by gravity as in the former plan, in which the empty cars when detached from the rope run by gravity into the empty siding, and the loaded cars descend by gravity around the curve to

the foot of the branch, where they lie ready to be attached to the rope.

When the pitch of the slope is so steep that the coal or ore falls out of the cars, during hoisting a gunboat is used or the cars are raised on a slope carriage—in either case, the arrangement of the tracks at lift landings is entirely different. With either a gunboat or a slope carriage, the arrangement of tracks on the slope is the same; but, in the former case, a connection between the slope and gangway tracks is often advisable. When a



gunboat is used, the gangway tracks run direct to the slope, and a tipple, or dump, is placed on each side to dump the mine cars over the gunboat; but when the cars are raised on a slope carriage, the gangway tracks run direct (at right angles) to the slope, to carry



the car to the cage or carriage. The floor of the cage is horizontal, and has a track on it that fits on the end of the gangway track when the carriage is at the bottom, and this track is arranged with stops similar to those on cages used in shafts. Another common arrangement of tracks at

the bottom of a slope is shown in Fig. 11. branch is made by widening the slope out near the bottom, and this, being a few feet higher than the main track, is used to run off the empties by gravity. The loaded cars run in by gravity around the curve to the foot of the slope in position to be attached to the rope.

In ascending, the loaded car forces its way through the switch, or the switch may be set by a lever located at the foot of the slope. When the

empty car descends, it runs in on the branch, where the chain is unhooked and thrown over in front of the loaded car, and runs around the curve into the gangway by gravity.

It will be observed that in this plan the loaded car (and consequently the

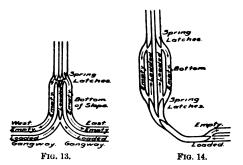
ttom men) stands on the track in line with the slope, and is in danger from wobjects falling down the slope, or from the breakage of the rope or coupgs; but this can be obviated by making the bottom on the curve. The ustration in Fig. 11 shows only one side of the slope; the other side is, of urse, similar.

All these plans necessitate the location of that part of the gangway near a slope. in the upper benches of the coal or near the top rock. The gang-

All these plans necessitate the location of that part of the gangway need the slope, in the upper benches of the coal or near the top rock. The gangay is then curved gently around toward the floor, so that, when it has been fiven far enough to leave a sufficiently thick pillar, the bottom bench is ached and the gangway is then driven along the bottom rock.

A very different bottom arrangement is shown by Fig. 12, which also presents a plan frequently adopted on surface planes. The two slope acks are merged into one a short distance from the bottom of the slope, and the opposite sides of the bottom two tracks curve around into the gangay on opposite sides of the slope. As these branches curve into the main angway tracks, a switch sends off a side track for the empty cars. The witch on the slope is either set by the car—and this can be done because ie next loaded goes up on the same side on which the last empty descended or by a lever located at the bottom.

It will at once be seen that in this plan no opportunity is afforded of andling the cars by gravity. The curved branches are made nearly level, and the momentum of the descending car, if quickly detached, is often ufficient to carry it partly or wholly around the curve, even against a slight



adverse grade. The disadvantage above noted of having the bottom in direct line with the slope (where there is danger from breakage and falling material) also obtains in this plan.

In the plan shown by Fig. 13, the grades may be so arranged that the cars can be entirely handled by gravity. The latches on the main-slope track may be closed automatically by a spring or weight, the loaded car running through them in its ascent on the slope, or both sets may be operated by a single lever at the bottom. The switch at the upper end of the central track (loaded) is set by a hand lever. All three sets may be linked together, so that they can all be properly set by a single lever. Reference to Fig. 11 will show that this is only a modification of that method. It requires space at the bottom for only three tracks, while Fig. 13 requires width to accommodate four tracks, and is objectionable because it is more complicated. The extra set of latches at the top of the central track, and the curvature of both main tracks into this central one, must inevitably cause much trouble

and delay from cars jumping the track at this point.

The plan shown in Fig. 14 is open to many of the objections pertaining to some of those already described, and which need not be reiterated here. It can only be employed in thick seams, or in seams of moderate thickness lying at a slight angle or dip.

In planning the arrangement of tracks on a slope, it is advisable to place as few switches as possible on the slope itself, to keep the main track

unbroken, to make the tracks as straight as possible, to have nothing ing at the bottom in direct line with the slope tracks, and to arrang

tracks so that cars are handled by gravity.

The arrangement of tracks near the top of the slope, and on the sur is often very similar to the bottom arrangements, as already describeds as all loaded cars (except rock and slate cars, which are run off on a sepa switch) are to be sent off on one track, and all the empties come in one same track to the head of the slope, and as there is usually abundance room for tracks and sidings, these top arrangements are, in a measure, m more easily designed. In some instances, the two main-slope tracks into a single track near the head of the slope—a plan somewhat similar the bottom arrangement shown by Fig. 12—and the cars are then brought the surface on one track, which, after passing the knuckle, bifurcates into loaded and empty track. A similar arrangement is frequently adopted slopes on which a carriage or gunboat is used. When the two main-sle tracks are continued up over the knuckle to the surface—the most comm and best plan-the arrangement of tracks and switches may be plann entirely with a view to the quickest and most economical method handling the cars.

Vertical Curves.—The vertical curves at the knuckle and bottom of a slow or plane should have a sufficiently large radius, so that when passing ow them the car will rest on the rail with both front and back wheels. The wheel base of the car must be considered in adopting the radius for the curves, for if the curve is of too short a radius, there is danger of the car

jumping the track every time it passes over the curve.

Tracks for Bottom of Shaft.—Fig. 15 shows the arrangement of tracks at the foot of a shaft, with one of the cages at surface. The grades should be so arranged that from the inside latches of the crossings the empty track

should have a slight down grade from the shaft, and the loaded track a slight down grade toward the shaft. The crossings and the short straight piece of road close to the shaft should be level.

Fig. 15.

As it is often desired to move empty cars from one side of the shaft to the

other, without stopping the hoisting, a narrow branch road should be cut through the shaft pillar, and used for this purpose. Where the pitch of the seam prevents this, a road should be laid alongside the shaft, room to accommodate it being cut out of the rock on the side most desirable. (See

also Shaft Bottom, page 276.)

In arranging tracks for shaft bottoms, at tops and bottoms of slopes, on coal bins, for mechanical-haulage landings, at foot of slopes or shafts, or in the body of the mine, it is customary to provide double tracks of sufficient length to hold the requisite number of wagons for economically operating the plant and with sufficient distance from center to center of tracks, and from centers of tracks to sides of entries, to easily pass around the wagons where it may be necessary, either in handling them, or in lubricating the wheels. For wagons with a capacity of from 1½ to 2 tons, it generally requires an entry to be about 15 to 17 ft. wide in the clear for ordinary landings in the body of the mine, while at shaft bottoms the necessary width ings in the body of the mine, while at shaft bottoms the necessary width may attain 17 to 18 ft. in the clear, owing largely to location and local requirements. The curved crossovers connecting the tracks at shaft bottoms should be designed with radii of as great length as can be introduced, thereby giving an easy running track. They should not be less than from 20 to 50 ft. on center lines for ordinary gauge of tracks, i. e., 36 to 44 in. On landings constructed in the body of the mine for the reception of empty and full wagons handled by mechanical haulage from shaft or slope, and from this point transported by animal power to the various working places in the mine, a grade of about 14 in favor of the loaded wagons to be handled by the stock will be found quite an assistance in delivering the wagons to the haulage. The frozs and switches for these landings as well

wagons to the haulage. The frogs and switches for these landings, as well as those required at the shaft or slope, should be formed of regular track rails, and can generally be arranged to be thrown by a spring or a conveniently located hand lever, as has been described, instead of being kicked

to position, as was the custom at one time.

Besides these usual arrangements of shaft-bottom landings, at many plants the natural grades of the entries can be taken advantage of in designing convenient and economical methods for handling the mine cars.

instance, where the coal is to be hauled from the dip workings of a ine by some form of mechanical haulage, and a summit can conveniently earranged for in the track on the same side of the hoisting shaft, at the roper distance therefrom, to accommodate the requisite number of loaded agons to be hauled, thus allowing them to run by gravity over, say, a Frace to the shaft, several varieties of empty-track arrangements can be bade. The most simple form is to have the empty wagon descend a short rade of from 4 to 54 when pushed from the cage by the succeeding full ne.

The momentum thus secured is quite sufficient to carry the car up an PDPOSINg grade of about 1.5%. It again descends on the same track, and seeing through an automatic switch, continues to the empty-car siding. From this latter point it is handled by the regular haulage machinery, and 1ts route passes around the shaft through an entry especially prepared for this arrangement. A shaft bottom so constructed is very economical to Operate, requiring but few men to handle the wagons.

Occasionally, it becomes more expedient to have a separate short haulage

draw the empty wagons to the main haulage when it cannot be easily arranged to construct a complete gravity landing. Several other modifications of such a general design can be made. All the different devices, however, depend largely on the local requirements of the particular mine

under consideration.

When endiess-rope haulage is employed, it is generally found to be most convenient to have the landings for full and empty wagons, in the body of the mine, reached by switches off of the main-haulage track, the cars coming on and leaving the main track at slight knuckles introduced in the track, in order to allow a place for the passing of the rope, which then moves along through a short cut or channel through the switch rails.

The flanges of the wagons pass over the rope in this manner without any

injury to it.
Surface Tracks for Slopes and Shafts.—The arrangement of the tracks on the surface naturally differs at every mine, owing to the different existing conditions. All surface roads should be so arranged that the loaded cars can De moved with the least possible power, always looking out for the return of the empties with as little expenditure of power as possible. To secure the running of the loaded cars from the mouth of the shaft or slope by gravity, a slight grade is necessary, the amount of which depends on the friction of the cars, which varies greatly. Care should be take that an excessive grade the cars, which varies greatly. Care should be take that an excessive grade is not constructed, or there will be trouble in returning the empties from the dump to the head of the shaft or slope.

The tracks connecting the top of the shaft and the tipple may be very short, or of considerable length, depending on the conditions at each mine. Usually from 20 to 60 ft. will be sufficient, although no definite rule can be

given for this.

There are two general arrangements of tracks about the head of a shaft: First, where the loaded cars are removed from the cage and the empty cars placed upon it from the same side of the shaft; second, where the loaded cars are removed from one side of the shaft and the empty cars returned to the cages from the opposite side of the shaft.

In either case there are usually several empty cars on the platform ready

to be put on the cages when the loaded cars have been removed.

Where the conditions are such that the loaded cars can be run by gravity to the dump, a good plan is to have a short incline, equipped with an endless chain, in the empty track. The empty cars can be run to the foot of this, hoisted by machinery to the top, and thus gain height enough to run them

hoisted by machinery to the top, and thus gain neight enough to the them back to the shaft or slope by gravity.

At the Philadelphia & Reading Coal & Iron Co.'s Ellangowan colliery, where the tipple at the head of the breaker is above the level of the head of the shaft, the following plan is used: The loaded cars are taken off the east side of the cages, and run by gravity to the foot of an incline, where the axles of the car are grasped by hooks on an endless chain and the car pulled up to the tipple. After being dumped, the car is run back from the tipple to the head of the incline, and is carried to the foot of the empty track of the incline by an endless chain. The foot of the empty track is experil feet bigher than that of the loaded track and the the empty track is several feet higher than that of the loaded track, and the cars are run by gravity around to the west side of the cages, and are put on from that side. The empty cars, as they run on the cage, have momentum enough to start the loaded car off the cage and on toward the foot of the incline. There are a number of hooks attached to both the empty and

loaded chain on the incline, and there are often several loaded and several empty cars on different parts of the plane at once., This arrangement permits of the hoisting of from 700 to 800 cars per day out of a shaft 110 yd.

deep, with single-deck cages.

Another excellent arrangement for handling coal on the surface is the vicention of Mr. Robert Ramsey, and has been adopted by the H. C. Frick Coke Co. and a number of other prominent operators. A description of this arrangement as applied at the H. C. Frick Coke Co.'s Standard Shafi sa sollows: The landing of the shaft is made slightly higher than the level of the tipple, which is north of the shaft. South of the shaft is located adouble steam ram, one ram being directly in line with the track on each cage. Directly in front of the rams is a transfer truck, worked east and west by wire rope. The loaded car on the cage is run by gravity to the tipple, where it is dumped by means of a nicely balanced dumping arrangement. As soon as it is empty it rights itself and runs by gravity alongsade the shaft to the transfer truck, which carries it up a grade to a point directly in line with the cage that is at the landing, and one of the steam rams pushes it on the cage, and at the same time starts the loaded car of toward the tipple. This second loaded car is then returned by the same means to the opposite cage. The whole mechanism is operated by one man, by means of conveniently arranged levers, each of which is automatically locked, except when the proper time to use it arrives. It is therefore impossible for the topman to work the wrong lever and put an empty car into the wrong compartment of the shaft. Besides the one man at the levers, there is but one other man employed at the tipple, and his work is solely to look after the cars when dumping. All switches are worked automatically, and the average holsting at this shaft is at the rate of 3 wagons per minute. The shaft is about 250 ft. deep, and single-deck cages are used.

The Lehigh & Wilkes Barre Coal Co. has a system in use at a number of collieries that has also proven very effective. In this system the loaded cars are run by gravity from the cage to the dump, and the empties are hauled from the dump back to a transfer truck by a system of endless-rope haulage. The transfer truck carries the car to a point opposite the back of the cage. The empty car runs by gravity to the cage, and its momentum starts the loaded car on the cage on its way to the dump. This system necessitates the employment of more topmen, but is a very good one. At the Nottingham shaft, which is 470 ft. from landing to landing, from 140 to 150 cars

per hour are hoisted on single-deck cages.

ORE DRESSING AND THE PREPARATION OF COAL.

CRUSHING MACHINERY.

The object of crushing ore or coal is: first, to free the mineral or other valuable constituents from the gangue, slate, pyrites (sulphur), or other worthless or objectionable constituents so that they can be subsequently separated; or, second, simply to reduce the size of the individual pieces and so get the material into a more salable or convenient condition for more salable or convenient condition for the salar or
so get the material into a more salable or convenient condition for use.

Selection of a Grusher.—The style of crusher employed is influenced by the following conditions: (a) The amount of material to be crushed in a given time. (b) The size of the material as it goes to the crusher. (c) The physical characteristics of the material to be crushed; that is, whether it is hard or soft, tough or brittle, clayey or sticky. (d) The object of the crushing; that is, whether it is to free the mineral constituents or simply to reduce the size of the individual pieces. (e) The character of the product desired; that is, whether an approximately sized product is desirable and whether dust or fine material is objectionable.

All crushing mechinger way be divided into the following classes: Isw.

All crushing machinery may be divided into the following classes: Jaw crushers, gyratory crushers, cracking rolls, disintegrating rolls, crushing rolls, roller mills, ball mills, stamp mills, hammers, and miscellaneous

forms of crushers.

JAW CRUSHERS.

With jaw crushers, the material is crushed between two jaws, one or both being movable. All jaw crushers have the common defect of imparting a considerable amount of vibration or shake to the framework of the building containing them, owing to the reciprocating motion of the heavy masses

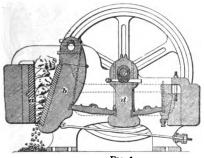


Fig. 1.

that comprise their crushing parts. There are three styles of jaw crushers in common use.

The Blake crusher is shown in Fig. 1, a being a fixed jaw and b a movable jaw that is operated by a toggle joint and the pitman d from a suitable crank-The jaw b is hung or pivoted at the top. advantages of this style are as follows: The large pieces of rock to be crushed are received between the upper part of the jaws, where the motion is least and the purchase or leverage greatest, so that they are broken with the small-

energy. The movement of the jaws is greatest at the discharge opening, thus affording a free and rapid discharge of the material crushed, and insuring a large capacity for the machine. The principal disadvantage is that the great variation in the discharge opening results in a considerable range in the size of the material delivered.

This style of crusher has found a wide field for the size of the material delivered.

TABLE OF BLAKE CRUSHERS.

of Re- ing Ca- ity. e Prod- Hour, ards, to		ght of aviest ce.	Total Weight.	Extreme Dimension						ed.	L .
Size ceiv paci	pproximate uct per Cubic Yar 2 Inches.	Weig Hei Plec	Total	Len	gth.	Brea	dth.	Hei	ght.	per Speed.	sepowe
Inches.	Appr CC 2	Lb.	Lb.	Ft.	In.	Ft.	In.	Ft.	In.	Proper	Horsel Requ
$3 \times 1\frac{1}{6}$ 6×2 10×4 10×7 15×9 15×10 20×6 20×10 12×30 15×30	Laboratory One Three Five Eight Nine Ten Ten Sixteen Twenty	40 560 1,800 3,800 7,400 7,800 5,300 8,100 14,200 14,200	100 1,200 4,900 8,000 15,500 16,000 11,200 18,300 33,000 35,000	1 2 4 5 6 6 5 6 7	1 10 0 1 6 6 6 3 10 10	0 2 3 3 5 5 2 5 8 8	6 1 3 9 0 5 11 9 4	0 2 3 4 5 4 5 6 6	10 3 9 5 11 11 6 11 4	250 250 250 250 250 250 250 250 250 250	6 8 15 15 15 20

and preparing it for other crushers, or for breaking large quantities of any material where an approximate sizing is not essential.

The **Dodge crusher**, Fig. 2, has a fixed jaw a and a movable jaw b, operated by a cam on the shaft g. The movable jaw is pivoted at the bottom, so that the minimum movement between the jaws is at the discharge opening. The advantage of this is that the least movement occurs at the discharge opening.

and hence the product is of a fairly uniform size, so that the crusher may be used as a rough sizing apparatus. The disadvantages are that the large

pieces of rock have to be crushed in the upper part of the space between the jaws, where the motion is greatest and the pur-chase or leverage least, thus requiring an excessive amount of power, especially when dealing with hard material. The movement of the jaw at the discharge opening is so much less than that above that there is danger of clogging or blocking the ma-chine, especially when working upon tough or sticky material.

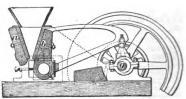


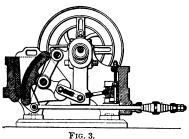
FIG. 2.

The capacity of the Dodge style of machine is less than that of the Blake. It is used largely as a secondary crusher, or for crushing comparatively small amounts of material where an approximately sized product is desired.

THE DODGE CRUSHER.

No.	Size of Jaw Opening.	Diameter of Pulleys.	Width of Belt Used.	Horsepower Required.	No. Tons per Hour, Nut Size.	Revolutions per Minute.	Weight Complete.
	Inches.	Inches.	Inches.				
1 2 3 4	$4 \times 6 \\ 7 \times 9 \\ 8 \times 12 \\ 10 \times 16$	20 24 30 36	4 5 6 8	2 to 4 4 to 8 8 to 12 12 to 18	1 to 1 1 to 3 2 to 5 5 to 8	275 235 220 200	1,200 4,300 5,600 12,000

Roll-jaw crushers, Fig. 3, have a movable jaw that has a rocking or rolling motion, subjecting the material to a rolling and squeezing action instead of a direct squeeze. The advantages are that, owing to the peculiar motion of the movable jaw, the material is crushed with comparative ease, and



that the product is approxi-mately sized. The disadvanmately sized. The disadvantages are that the discharge is so small that there is danger of blocking the machine, and the capacity is small when compared with the Blake crusher. The Sturtevant rolljaw crusher and the Schranz rock breaker work on this principle.

Gyratory Crushers. — These crushers, Fig. 4, are all large capacity, continuous action crushers. a is a ring or hopper against which the material is crushed by a conical head c, which fits on a shaft g, the bottom of which is placed in

an eccentric bearing so that the amount of space between a and c varies as the head rotates. The material to be crushed is dumped into the receiving hopper h, and the machine is thus automatically fed.

The advantages of this style are that the large pieces of material are received at the top of the jaws, where the motion is least and the leverage purchase greatest, thus reducing the work necessary in this heavy preliminary crushing. The relative moveor

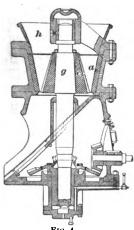


Fig. 4

ment between the crushing members is a maximum at the discharge opening, but the amount of this movement is so small that the product is approximately sized. The fact that the maximum movement is at the point of discharge assures a free discharge. There is practically no shaking imparted to the building by gyratory crushers. Their capacity is very great, and with a large size, material may be dumped into the hopper h directly from the cars. For small capacity a gyratory crusher is more expensive than a jaw crusher.

Frequently, where very great amounts of material are to be crushed, large gyratory crushers are used as secondary crushers after jaw crushers of the Blake pattern, the discharge from the jaw crushers ran-ging from 6" to 12" cubes, and that from the gyratory crushers from 14" to 24" cubes.

(See table on page 422).

ROLLS.

Cracking Rells.—This is a general name applied to rolls having teeth, which are usually made separate and inserted. These rolls, Fig. 5, are employed for breaking coal, phosphate rock, etc., the object being to break the material into angular pieces with the smallest possible production of very fine material. The principal field for cracking rolls is in the preparation of anthracite coal, and the exact style or design of the roll depends largely on the

physical condition of the coal under treatment. In most cases, the rolls are constructed with an iron cylinder having steel teeth inserted, the

size, spacing, and form of the teeth depending on the size and physical condition the material to be broken. Cracking rolls vary from 12 to 48 in. in diameter and from 24 to 36 in. in face width. The teeth of the larger sizes are from 3 to 31 in. high, and of the smaller 1 in. or less.

The average practice in the anthracite regions of Pennsylvania is to give the points of the teeth a speed of about 1,000 ft. per minute, though the speed in different cases varies from 750 to 1,200 One of the ft. per minute. largest anthracite companies has a standard roll speed of 97.5 R. P. M. for the main rolls and 124.5 R. P. M. for the pony rolls. The harder the coal, the faster the rolls

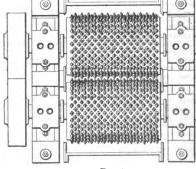


FIG. 5.

can be run. If run slow and overcrowded, the rolls will make more culm than when driven at a proper speed. One advantage of comparatively fast driven rolls is that the higher speed has a tendency to free the rolls by throwing out, by centrifugal force, any material lodged between the

teeth. In one test it was found that less fine coal was produced at 800 ft. for minute, but that the rolls blocked at this speed and hence had to be driven 1,000 ft. per minute.

In one case a pair of main rolls 24 in. in diameter, 36 in. face, running at 1,000 ft. per minute, handled 2,500 tons of coal in 24 hours. A pair of 19" × 24" main rolls run at 1,000 ft. per minute handled 300 tons mine run in 10 hours.

A well-known maker of rolls for crushing bituminous coal gives a speed of 100 to 180 k. P. M., according to the output required, for rolls 24 in. in diameter and 33 in. long. As a rule, cracking rolls are never run up to their full capacity, as is the case with crushing rolls.

The form of the teeth varies greatly, but, as a rule, the larger rolls have straight pointed teeth of the sparrow-bill or some similar form, Fig. 6 a. The old curved, or haw k-billed, teeth, Fig. 6 b, have now gone almost wholly out of use.

On small sized rolls, rectangular teeth with a height equal to one side of the square base are frequently employed, and these may be cast in segments of manganese or chrome steel.

Corrugated rolls have teeth or corrugations extending their entire length. They were first introduced by

ě POWER DIMENSIONS, WEIGHTS, CAPACITIES, AND REQUIRED

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		Weight	Breaker.		Pounds.	3,300	5,600 7,800	22,586 5,586	40,500	86.80 000,00 000,00
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423 ROLLS.

fr. E. B. Coxe, at Drifton, Pa., but they have not come into general use wing to the fact that, while they break some coal fairly well, in most ases it has been found that a continuous edge causes too much disinteration along its length, while a point splits the coal into three or four ieces only, all the cracks radiating from the place where the point strikes, hus producing very much less culm. Another advantage possessed by the oothed rolls is that if anything hard passes through the corrugated roll and breaks out a piece of the corrugation, the entire roll

s ruined, while, in the case of the toothed rolls, any one

of the teeth may be replaced.

Disintegrating rolls and pulverizers are sometimes used to educe coking coal to the size of corn or rice before introlucing it into the ovens. One roll is driven at double the lucing it into the ovens. One roll is driven at double the speed of the other, the slower roll acting as a feed-roll, and the other as a disintegrator. The slower roll is commonly liven at from 1,800 to 2,000 ft. per minute peripheral speed, and the faster roll at from 3,600 to 4,000 ft. per minute. The teeth are always fine, rarely being over \(\frac{1}{2}\) in some cases, the inner roll is provided with a series of saw teeth from \(\frac{1}{2}\) in. high and having about \(\frac{1}{2}\) in jtch, the individual teeth being set so as to form a slight spiral about the body of the roll. The other roll is provided with teeth having their greatest dimension in the direction of rotation, so that they tend to cross the te

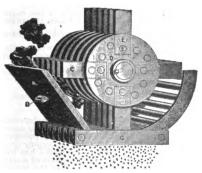


FIG. 6.

in the direction of rotation, so that they tend to cross the teeth on the opposite roll. These teeth are also set so as to form a slight spiral, and thus prevent blocking. In other cases, the teeth on both rolls are set in the form of

Quite a steep spiral.

Hammers.—For the reduction of coal, crushers employing hammers have been used, Fig. 7. The crushing chamber is usually of a circular or barrel form, and the crushing is done by means of hammers pivoted about a central shaft. These swing out by centrifugal force and strike blows upon the coal to be broken. When it is reduced sufficiently fine, it is discharged through bars or gratings at the lower portion of the machine. This style of machinery is usually employed in preparing coal for coke ovens, thus occupying the same

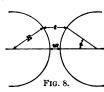


field as the disintegrating A No. 3 pulverizer of rolls, this type will crush 50 to 75 tons per hour run of mine, down to in., or it will crush 100 tons per hour of slack. Such a machine occupies about 8 sq. ft. of floor space and requires 25 to 30 H. P. to run it.

Crushing Roils.-The principal representative of this type of machine is the ordi-nary Cornish roll having a fairly wide face and rather small diameter. The diameter of these rolls was kept down for a great many years on account of the fact that the chilled cast-iron shells could not be obtained in large sizes and were expensive and hard to handle. With the advent of the rolled-

steel shells, it became possible to employ larger diameters and higher speeds. Rolls of the Cornish type vary from 4' face and 9' diameter to 16' face and 42' diameter. The distinctive feature of the Cornish roll is a comparatively wide face compared with the diameter, and a rather slow peripheral speed. Many of the modern Cornish rolls are provided with rolled-steel shells, especially when employed for very fine that these shells are of a more representative to the face that these shells are of a more representative. crushing, owing to the fact that these shells are of a more uniform texture, work more evenly, can be worn much thinner before being discarded, and can be trued up with less difficulty than is the case when chilled iron is employed. To guard against the bending of the roll shaft or breaking of the machine in case any hard material (such as a pick or hammer) gets between the rolls, one roll is mounted in a movable bearing and kept in place by a compressed spring washer. This washer is composed of two plates between which are placed one or more steel springs. The plates are kept together by several small bolts, which are screwed up so as to compress the springs to a certain degree. Then the entire arrangement is employed as a washer on the rod that keeps the rolls together. Should the pressure exerted on the rolls exceed that already exerted in the spring, the plates would be brought nearer together and the roll allowed to move back and pass the hard substance, but at any pressure below this, the roll acts as if placed in a fixed bearing.

Cracking, corrugated, and disintegrating rolls are usually provided with breaking pieces back of one of the rolls, so that in case any extra hard piece passes through the rolls the breaking piece will give way, allowing the rolls to move back and thus prevent the bending of the shaft or breaking of the machine itself. Compressed spring washers have never come into general use in connection with this style of machinery.



Amount Crushed .- The amount of material that can pass between any pair of rolls is proportionate to the number of square feet of roll surface passing per minute; hence, the capacity may be increased by keeping the face width the same and in-creasing the speed, or the same capacity may be obtained by reducing the face and increasing the speed.

According to Stutz (A. I. M. E. IX, page 464). Fig. 8.

if the distance between the contact points of the material with the rolls be t. Fig. 8, the distance between the crushing face of the rolls v. the angle a, as shown in the figure, and R the radius of the roll, then

$$R = \frac{t - w}{2 \text{ vers. sin } a} = \frac{t - w}{2(1 - \cos a)}.$$

According to Pernolet, the amount of material that may be crushed by a pair of rolls in a given time is equal to one-fourth or one-fifth of a band or layer whose length is the circumference of the roll multiplied by the number of revolutions; whose width is the length of the rolls, and whose thickness is equal to the space or distance between the rolls.

Or, $Q = \frac{d \pi n l w}{d w}$ where d = diameter of rolls; $\pi = 3.14$; n = number of revolutions in the given time; l = length of rolls; w = space between rolls: and $\frac{1}{2} = coefficient$, to allow for the irregular feeding of the material and the space between the pieces.

The Denver Engineering Works gives the following formulas for the capacity of crushing rolls:

For
$$14'' \times 27''$$
 rolls, $T = 7.725 RS$.
For $16'' \times 36''$ rolls, $T = 11.775 RS$.
For $12'' \times 20''$ rolls, $T = 327 RS$.

capacity of crushing rolls: T= tons per hour; R= rev. per min.; S= mesh (inches). For $14''\times 27''$ rolls, T=7.725 RS. For $12''\times 20''$ rolls, T=11.775 RS. For $12''\times 20''$ rolls, T=327 RS. Speeds.—The pressure on the bearings necessary to crush ore depends directly on the face width, and hence if the capacity can be kept the same and the face width decreased, it is evident that there will be less pressure on the bearings and less loss in friction. The difficulty of keeping the bearings cool when crushing hard rock with the old Cornish rolls has led to the adoption of high-speed, narrow-faced rolls for certain classes of work. One objection to running the small diameter rolls fast is that the larger One objection to running the small diameter rolls fast is that the larger pieces of ore have a tendency to dance on the face of the rolls rather than to be crushed, while the bite is better when the speed is slower.

The advantages of high-speed, narrow-faced rolls are: greater capacity for a given bearing pressure; less loss of power from friction; less dancing of the ore on the roll face, owing to the fact that the angle of approach between the surfaces of large rolls is more acute than with rolls of a small diameter. High-speed, large-diameter rolls will handle coarser material and hence make a greater range of reduction than small-diameter rolls. The disadvantage of high-speed rolls is that they tend to hammer and pulverize the ore, so that with very brittle minerals a high speed may be detrimental. In general, it may be stated that for crushing to any definite size with the lowest possible production of very fine material, rolls are the best form of machinery on the market. For fine crushing of brittle material, quite slow speeds may give the best results.

The accompanying table gives some facts in regard to the crushing-roll practice of several manufacturers, the data having been taken from their catalogues or other information furnished by them.

CRUSHING ROLLS

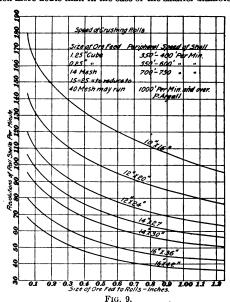
	CR	USHING ROLLS	3.	
Name.	Size. Inches.	Peripheral Speed in Ft. per Min.	Spring Pressure in Lb. per In. of Face Width.	Character of Rolls.
Frazer & Chalmers	24×8 36×16	600-1,500	4,000 for hard quartz.	Cornish.
Frazer & Chalmers	44 × 5 56 × 8	2,200-2,300		Narrow face, high speed.
Earle C. Bacon		1,000		Cornish.
Sturtevant Mill Co.	16 × 3 27 × 5	3,000		Special cen- trifugal.
E. P. Allis Co	20×12 26×14 30×14 36×14	800		Cornish.
E. P. Allis Co		1,885		Narrow face, high speed.
Colorado Iron Works	20×12 27×14 36×16 40×16	600	4,000 for hard rock. 4,800 for very hard rock.	Cornish.
Colorado Iron Works	36×6 42×6 54×8	2,100-2,800		Narrow face, high speed.
Denver Engineering Works Co	16×10 to 42×16	350–100	3,500-4,500	Cornish.
Gates Iron Works	9×4 26×15 36×15	470-850	2,266-3,333	Cornish.

The Gates Iron Works has furnished the following formulas relating to crushing rolls, in which D= diameter of roll in inches; N= number of R. P. M.; S= maximum size of ore cube in inches fed to the rolls; S'= maximum size of cube for a given diameter of roll.

It will be seen from the first of these formulas than N is an inverse function of S, which agrees with the results shown in the previous diagram. As a rule, it is best not to try to run rolls up to the maximum size that they

will crush, but to feed smaller material to them.

The Denver Engineering Works Company has furnished the diagram, Fig. 9, and formulas relating to rolls. This diagram serves very well to illustrate the fact that small rolls do not grip or crush large pieces as well when running at comparatively high peripherial speeds as when running at slow speeds. In the case of the 10"× 16" roll, a difference of from 1" to \(\frac{1}{2}\)" cube size made a difference of 20 R. P. M. in order to obtain the most effective crushing speed, and the difference between \(\frac{1}{2}'' \) and \(\frac{1}{2}'' \) cube sizes made a difference almost as great. It will also be noticed that the larger diameters, as, for instance, the \(42'' \) roll, are not so greatly affected by this cause, owing to the fact that the effective or crushing angle between the rolls is much more acute than in the case of the smaller diameters.



CRUSHING MILLS.

Radial Roller Mills.—In this type of mill, the crushing is performed on a ring or die by a series of heavy rolls pressing on it by gravity. In some cases, the rolls travel around on the die and in others the die travels in relation to the rolls. Fig. 10 represents one form of Chilian mill that is the leading type of this class.

The peculiarity of the class.

The peculiarity of the grinding action of the radial rolling mills is that it is not a pure crushing action, but a triturating or grinding action as well, owing to the fact that while the different portions of the face of the roll are all traveling at the same speed, the outer portions have to travel over a greater length of ring than the inner portions, so that there is only one line along which true crushing action occurs. Some manufacturers have made the crushing ring and the rollers both with coning faces, the vertices of both cones meeting at a common point. This has resulted in a true crushing action, but for some classes of work the triturating action is to be preferred, as, for instance, in the grinding of silver ores for the patio process of amalgamation.

Centrifugal Roller Mills.—In centrifugal roller mills, the crushing is accomplished between rapidly moving rolls and the inside of a stationary die or ring. The Huntington mill, Fig. 11, is one of the principal representatives of this class of machinery. The rollers c are supported from bearings c and are carried rapidly around by means of the frame a and the shaft g. The ore is crushed against the ring d. In order to prevent the accumulation

if ore below the rollers, and to throw it out for crushing, scrapers f are prorided. The crushed ore discharges through screens, as shown in the illusration. There are many styles of this class of machinery having different numbers of rollers, varying from 1 up, and some machines have been intro-

duced combining a portion of the action of radial and centrifugal machines, the faces of the die or ring being at an angle and the rollers being mounted in inclined bearings so that they tend to crowd out and down upon the ring. Centrifugal roller maills have found two especial fields in concentration works, one for crushing clay or soft ores containing free gold, and the other for regrinding middlings for further concentration. Rolls of this type are also extensively employed in grinding cement and phosphate rocks.

Ball Mills.—There are two types of ball mills: (1) those in which the crushing is performed by balls traveling in a fixed path, and (2) those in which the crushing is per-

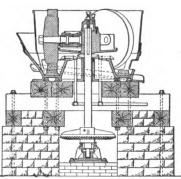


FIG. 10.

formed by a large mass of balls of various sizes rolling over one another. In the first type the balls travel in a fixed path, track, or race that may be either vertical or horizontal. Where it is vertical, the balls must be driven at such a rapid rate that their centrifugal force will keep them in contact with the crushing ring or track. This form may be likened to a bicycle ball bearing on a large scale, the crushing being accomplished between the balls and the race or track. The serious objection to this class of ball mills is found in the uneven wear of both the balls and the race, so that the work soon becomes unevenly distributed, and also in the fact that the balls cannot be used after they have been worn to a slight extent.

In the second class of machines the balls are introduced into a large barrel or chamber, where they roll over one another, the ore being crushed

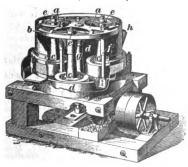


Fig. 11.

between the different balls and between the balls and the lining of the chamber. In this style of machine the crushed material may be discharged through openings in the periphery or through openings in one end of the barrel. One great advantage with this style of mill is that the balls can be entirely worn out and it is only necessary to charge a sufficient number of new balls with the ore each day to make up for the wear of those in the mill.

STAMPS.

Gravity stamps are especially well suited for material the valuable portion of which does not have a tendency to slime.

The fact that these stamps are very simple in construction, easy to transport and erect, as well as to operate, gives them a decided advantage over other forms of crushers. Fig. 12 illustrates a 10-stamp battery of the gravity type.

Fig. 13 is a detail of the mortar stamp heads and dies. The mortar a is placed. on a suitable foundation of timbers b and the ore crushed on dies a by the stamps a, which are secured by means of tapered joints to the heads or bossis b. The stems a are attached to the heads b and the whole lifted by the came (shown in detail in Fig. 12). The came operate under tappets on the stems, as shown in Fig. 12. As the cam operates under the edge of the tappet, it not only lifts the stamp, but gives a partial rotation, thus equalizing the wear on both the stamp and die. The ore is fed in at the back of the mortar and the crushed material discharged through the screen, as shown in Figs. 12 and 13. Usually a single screen at the front is employed, but sometimes two or nore upon different sides of the mortar may be introduced. For treating free-milling gold ores in which the gold occurs in rather large grains free from iron pyrites, the *California* style of battery was developed, the characteristics of which are a small drop (4 in. to 6 in.), low discharge (4 in.), a heavy stamp (750 to 1,000 lb.), and a high speed or number of drops per minute (90 to 105). The advantage of this style is rapid crushing, but the majority of the gold had to be saved on apron plates outside the mortar.

For working ores that contain large quantities of iron pyrites with the gold values occurring in the cleavage planes of the pyrites, the Gilpin County, Colo., style of battery was developed. This is characterized by a high drop (18 to 20 in.), a high discharge (14 in.), a light stamp (550 to 600 lb.), and

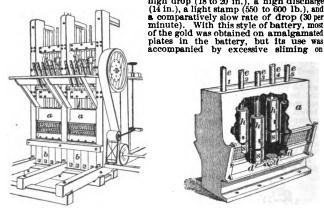
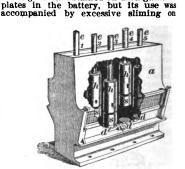


FIG. 12.



With this style of battery, most

FIG. 13.

account of the fact that the high discharge kept the material in the mortar for a long time, and subjected it to repeated treatment.

Modern practice tends toward the use of rather heavy stamps (about

modern practice tends toward the use of rather neavy stamps (about 1,000 lb.), quick drop (90 to 105 per minute), and low discharge (4 to 6 in). The advantages are that the capacity of the battery is very great and the sliming reduced to a minimum. If the ore contains sulphides carrying gold, they are separated by concentration upon vanners or bumping tables, and subsequently treated by chlorination or smelting. If the apron plates do not catch the major portion of the values, the tailings may be treated by the cyanide process. This last method is that employed at many large gold mines, especially those of the Transvaal in South Africa.

Order of Drop.—There is much diversity of practice in this respect. It is desirable to drop the stamps in such rotation as to insure an even distribution of the pulp on the several dies. Adjacent stamps should not drop consecutively, as this occasions accumulation of the pulp at one end of the mortar, in consequence of which the efficiency of the stamps at that end is reduced by having a decreased height of drop and a cushion that retards the pulverization of the ore. The stamps at the other end of the mortar have too little work, and are liable to "pound iron." The order of drop 1, 4, 2, 5, 3

429STAMPS.

seems to best fulfil the requirements. It gives a good splash and satisfactory results in other respects. The order 1, 5, 2, 4, 3 is also extensively There are several other orders of drops in use, but the two just

nentioned are generally preferred.

In large mills, the standard drop is given as 1, 7, 3, 9, 5, 2, 8, 4, 10, 6, with 1, 8, 4, 10, 2, 7, 5, 9, 3, 6 as a close favorite; while 1, 5, 9, 7, 3, 2, 6, 10, 8, 4 and 1, 5, 9, 3, 7, 10, 6, 2, 8, 4 are used.

Speed of Stamps.—Heavy stamps and stamps having high drops should have correspondingly low speed. With 900- to 950-lb. stamps, having 6" to 7" drop, the speed should be from 85 to 95 drops per minute. With doublearmed cams, the speed must not be great enough to bring the cam into collision with the falling tappet, i. e., the interval between the revolutions of the cam must be sufficient to give the tappet time to finish its drop. When the cam strikes the descending tappet, a shoe, boss, or tappet is often dislodged, and breakage is imminent. A fast drop produces a good splash,

which is very desirable for battery amalgamation.

Shoes and Dies.—Shoes and dies are either of iron or steel. In most mills, remote from foundries where transportation is an important item in the cost of shoes and dies, steel shoes and dies have replaced those of iron. Chrome steel shoes and dies have been introduced and have proved superior. In some mills, steel shoes and iron dies are used. The iron dies wear more evenly with steel shoes than the steel dies do. The life is about 21 to 3 times that of iron shoes and dies, and the cost about twice as great as those of iron. The mixture of steel (from the old chrome steel shoes and dies) with iron produces shoes and dies that wear considerably longer than those of pure iron, and may be advantageously introduced where there is no other disposition possible for the old steel, because of want of local facilities for the utilization of this residue. In many districts, the old iron shoes and dies are sold to local foundries for from 11 to 2 cents per lb.

The weights of the shoes bear a certain relation to the weights of the tappets, stems, and bosses. Chrome steel shoes made for stamps of 850 to 950 lb., weigh from 150 to 155 lb., and measure about 9 in. in diameter by 7½ to 8 in. long. The neck is from 4½ to 5 in. long, with a taper to correspond to the socket of the boss or stamp head. Iron shoes are usually from 15 to 20 lb. lighter than the above weights. The chrome steel dies weigh from 110 to 125 lb., and measure (where shoes of the above dimensions are used) 9 in. in diameter by 4 to 44 in. in height, with a rectangular foot-plate 104 in. by 91 in. by 1 in. thick. Iron shoes usually weigh from 20 to 25 lb. less than

the above weights for steel.

Life of the Shoes and Dies.—There are many conditions that affect the durability of shoes and dies, as, for instance, the hardness of the rock, the weight, speed, and height of drop of the stamp, the manner of feeding the ore, etc. Iron shoes of good quality last from 30 to 47 days. Old shoes wear usually down to 1½ in. or 1 in. in thickness, and weigh about 25 or 40 lb. Old dies usually wear down to about 11 in. in thickness, and weigh from 20 to 50 lb. The consumption of iron or steel in shoes and dies depends on the character of the ore crushed. Other conditions being the same, it will depend on the coarseness of the stamping and the height of discharge. Dies wear less rapidly than the shoes, as they are protected by the thickness and the pulp, which covers them to the depth of from 1½ to 3 in. But while the actual wear of dies is less than that of the shoes, the life of the dies is shorter than that of the shoes, owing to the fact that the shoes have several inches greater length of wearing part than the dies. The consumption of iron for shees and dies per ton of ore crushed is, in California, from 11 to 3 lb. To obtain the maximum crushing capacity of the battery, the dies must be kept as high (with reference to the lower edge of the screens) as is compatible with the safety of the screens and with successful amalgamation in the battery. To prevent the pounding of iron, it is necessary to preserve more or less uniformity in the level of the dies. Should one die in the battery project much above the others, little or no pulp would remain upon it, and the shoe would consequently drop upon the naked die.

Cams, Stamp Heads, and Stems.—Cams and stamp heads ought to last several years. They are usually broken through carelessness. The stems break at the socket of the stamp head. Stems are reversible; when broken, they may be swedged or planed down and additional lengths welded on

when necessary.

Tappets.—When there is much grease on the tappet or cam or when the

tappets have so worn that the face of the cam strikes a grooved instead of tappers have so worn that the face of the cam strikes a grooved instead or, level face on a tappet, the rotary motion is greatly impaired. Tappets is for several years, from 4 to 5 years being their usual life. Sometimes the are broken by being too tightly keyed. When their faces are worn, the are planed down. They are reversible, so that when one face has been worn as far as possible, the other face is placed downwards. They are usually of steel, and weigh about 112 lb. when 900-lb. stamps are used.

Battery Water.—The amount of water fed to the battery depends on the character of the ore and the size of the screen. Clayey and highly sulpher reted opes require the maximum amount of water. The amount of water used per ton of ore stamped varies from 1,000 to 2,400 gallons. The mean amount used per ton of ore stamped is about 1,800 gallons. The mean amount used per ton of ore stamped is about 1,800 gallons. The mean amount used per ton of ore stamped is about 1,800 gallons. The mean amount used per battery should be provided. In winter, when the battery water is chilly, it should, when possible, be heated to tepidity, as this promotes amalgamation. A high temperature should be avoided, as it renders the quicksifver too lively.

Duty of Stamps.—The capacity of gravity stamps varies from a little over 1 ton per stamp for 24 hours to as high as 4 tons per stamp for 24 hours depending on the quality of the ore. Usually, an average of from 1.7 to 2 tons per stamp for 24 hours in a combination mill would be good practice. while where the ore is crushed to a rather coarse screen and the tailings treated with the cyanide process, a larger capacity is usually obtained.

The number of tons of ore crushed per stamp depends chiefly on the weight of the stamp, the number of drops per minute, the height of drop the height of discharge, the size of the screens, the width of the mortar, and chiefly on the character of the ore. Hard ores and ores of a clayey nature (from the difficulty experienced in discharging the clayey pulp) decrease the duty of the stamps. About 2½ tons per stamp in 24 hours is the average duty of the stamps. The discharging capacity of a mortar day of the stamp in California. The discharging capacity of a mortar day of the stamp in California. depends on the height and size of the discharge opening, the character of the screen, and the width of the mortar discharge, as will be illustrated from two well-known mills.

The Homestake Mill uses an 850-lb. stamp dropped 9 in., 85 times per minute, developing 78,030,000 ft.-lb. in 24 hours, and crushing 4½ tons of rock, or 1 ton for every 17,340,000 ft.-lb. developed.

The Caledonia Mill uses an 850-lb. stamp, dropping 12 in., 74 times per minute, crushing 3.3 tons, of rock and developing 90,576,000 ft.-lb. in 24 hours, or 1 ton to every 24,447,272 ft.-lb. developed. Although developing more foot-pounds in 24 hours, and therefore seemingly more efficient, yet it crushes less rock than the former. The reasons for this are (1) that the rock is harder than that of the Homestake; (2) the width of mortar is 16 in against 13½ in.; and (3) the 2" recess for the 8" copper plate below the feed. On the other hand, the Caledonia has a lower discharge from the mortar, using 6 in. against 10 in. in the Homestake; but this advantage is again neutralized by a smaller screen, the Caledonia using 258 sq. in. against 376 sq. in. of the Homestake.

Horsepower of Stamps.—The H. P. of a stamp battery =

No. of stamps \times wgt. of each stamp \times No. of drops per min. \times drop of each in in.

 $12 \times 33,000$

The weight of each stamp is equal to the sum of the weights of the stem. tappet, stamp head, and shoe. To the nominal H. P. add 25% for friction of

tappet, stamp nead, and snoe. To the nominal H. P. and 224 for inciden of machinery in calculating driving H. P.

Cost of Stamping.—The cost of stamping varies from a little over \$1.00 per ton up. The Montana Co., Limited, operating a 60-stamp combination mill, in 1888 treated 40,530 tons of ore at \$1.13 per ton. In Australia, stampmill costs have been reported varying from \$1.30 to \$2.50 per ton where fairly favorable conditions for working could be obtained. Figures from other districts compare favorably with these, but it would be impossible to give any absolute rule by means of which the cost can be determined in advance without an intimate knowledge of the character of the ore and advance, without an intimate knowledge of the character of the ore and the local conditions.

Pneumatic Stamps.—This is a name given to a form of large capacity power stamp, the head of which is connected to a piston in an air cylinder. The cylinder is raised and lowered by power, the air forming an elastic connection by means of which the stamp is operated. They are quite extensively employed in crushing tin ore, but have never come into general use for other purposes. The capacity is as high as 30 tons per 24 hours.

Power Stamps.—Various forms of stamps have been brought out at differtimes, intended to operate by power like a trip hammer, or in which the stamps were connected directly to the cranks operating them by means of spring joints. Nearly all of these forms have failed on account of exces-

sive wear, small capacity, and the large amount of power consumed.

Steam Stamps.—The large capacity steam stamp, which was evolved in connection with the concentration of the Lake Superior copper ores, consists of a steam cylinder in which operates a piston, to the stem of which the stamp head is directly connected. Machines of this style are usually made very large and heavy, frequently extending through two or three stories of the mill, and having a capacity equivalent to from 60 to 100 ordinary gravity stamps. In most forms, live steam is admitted on top of the piston during the descent of the stamp, thus increasing the force of the blow. For lifting the stamp, the steam is throttled so that a lower pressure blow. For lifting the stamp, the steam is throttled so that a lower pressure is employed. The discharge is usually through a coarse screen, #' to \(\frac{4}{1} \) mesh not being uncommon. One interesting fact connected with the large steam stamps is that their heavy blows do not cause as excessive sliming as the lighter gravity stamps, and on this account this form of stamp has been introduced in some cases for crushing free-milling gold ores.

For prospecting work, for testing properties, or for operating small properties, a number of forms of portable or semiportable steam stamps have come out during the last few years. One of these (the Tremain) is illustrated in Fig. 14. In this form, two pistons work in cylinders side by side and strike alternate blows in a common mortar. The steam is introduced at full boiler pressure on

mortar. The steam is introduced at full boiler pressure on the lower side of the cylinder, which, owing to the large diameter of the piston rod, has a small area. This high pressure steam is then allowed to expand on to the top of the piston, thus urging it down with greater force than its own weight would. These steam stamps can be run at a much higher speed than gravity stamps, and hence have a greater capacity. In the figure shown, three screens are employed, one in front and one at each end of the mortar. There are several other forms of portable steam stamps manufactured. They all have the advantage that for a small property they can be installed with much less trouble than any other form of crusher, owing to the fact that no steam engine is required and the steam necessary to drive them can usually be obtained from the boiler operating the hoisting engine, pumps, etc.

Miscelleneous Forms of Crushers.—Most crushers can be classed under one of the previous heads, but there are some

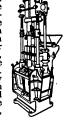


Fig. 14.

forms that depend on the material itself to do the crushing. For instance, in the preparation of coal for coke ovens, there has been a combined crusher and separator invented that may be described as follows: A large horizontal drum or cylinder, provided with screen openings around its periphery, is mounted in a horizontal position. The coal to be separated is fed into one end and is caught by shelves or plates projecting radially into the cylinder. These lift the material to the upper side from which it falls by gravity and stribes the hottom that a proper side from which it falls by gravity and details to the hottom that a proper side from which it falls by gravity and stribes the hottom that a proper side from which it falls by gravity and strikes the bottom, thus crushing the softer parts. The sulphur and slate, being harder than the coal, are not crushed by the same height of fall, and hence, by a proper adjustment of the diameter of the cylinder, the coal may be crushed and discharged through the screen while the slate and sulphur will pass out at the opposite end of the cylinder.

SIZING AND CLASSIFYING APPARATUS.

Stationary Screens, Grizzlies, Head-Bars, or Platform Bars.-These are the various names given to an inclined screen employed for removing the fine material from the run of mine so that only the coarse portion will be passed to the crushers. At concentrating works, the term grizzly is usually employed, and a common form is shown in Fig. 15. This is composed of flat bars held apart by cast-iron washers through which the bar bolts are passed to hold the entire frame together. Grizzlles are usually placed at an angle of from 45° to 55°, and ordinarily, for the head of a large concentrating works, they are from 3 to 6 ft. wide and from 8 to 12 ft. long, the amount of space between the bars depending on the size of the run-of-mine material and on its subsequent treatment.

In the anthracite coal breakers, the terms platform bars or head-bars are usually employed, and these bars are made of 14" to 2" round iron placed at an inclination of 5 in. to 1 ft., the spacing depending on the size of coal it is desired to make in the breaker.

At the present time, in accordance with an agreement between the operators and the miners' officials, the standard size for a bituminous lump

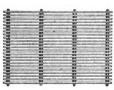


FIG. 15.

is, the standard size for a breamford composered (the bars are called a screen) for Ohio. Pennsylvania, Indiana, and Illinois is 12 ft. long and 6ft. wide over the screen surface. The screen consists of 6 bearing bars 4 in. by \$\frac{1}{2}\$ in of soft steel and 39 steel screen bars. Fig. 16, with 1\$\frac{1}{2}\$ in. clear space between bars. In Iowa. the same sized bar is used, but the space be-tween the bars is 11 in. In the other Western and Southern States there is at present no standard.

The standard nut-coal screen for Pennsylvania and Ohio is ‡ in. space, but ‡ in. is sometimes used and the nut screen is often

varied to suit the special trade. At present very few pea screens are used, but if placed under a \(\frac{1}{2} \) nut screen, the space is from 1 in. to 1 in. In the Pittsburg region of Pennsylvania, all coal passing over 1" screen is called stack, while, on the Monongahela River, coal passing through 14" screen is called slack and is used in stokers. Many companies are at present crushing their run-of-mine coal to make slack suitable for stokers.

It is difficult to classify bituminous coal by sizes, but as nearly as possible the following seem to be the standard: Lump, all coal passing over 14" screen; nut, all coal passing through 11" openings and over 1" openings; stack, all coal passing through 1" screen. If a pea-coal screen is used, all coal passing over 1", 1", and 1" would be pea coal, and that passing through 1", 1", or 1" would be slack.

Adjustable Bars.—The top of the bar is cylindrical and projects beyond the Aussace Data.—In copor the bar is compared and projects beyond the web which supports it, so that any lump which passes through the upper part will fall freely without jamming. The two ends of the bar are \(\mathbf{V}\) and and fit into similarly shaped grooves, so that the bars can be set at distances from each other varying with the sum of the width of the bases of the triangles, the usual opening being about 4 in. These bars are generally 4 ft. long, but they can be of any size.

Finger bars are screen bars that are fixed at one end only, and the bars are narrower at the lower end than at the top, so that the spaces between them are wider at the bottom than at the top, thus giving less tendency for

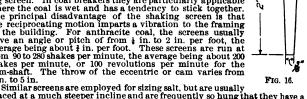
pieces of material to become wedged between the bars.

Movable or oscillating bars are screen bars that are attached to eccentrics at their lower ends, the eccentrics of adjoining bars being

This movement throws the material forplaced 180° apart. wards and the bars do not therefore require nearly the same

inclination as fixed bars.

Shaking acreens have an advantage in that the entire area of the screen is available for sizing, and hence a greater capacity can be obtained from a given area of screening surface. They also occupy less vertical height than a revolving screen. In coal breakers they are particularly applicable where the coal is wet and has a tendency to stick together. The principal disadvantage of the shaking screen is that the reciprocating motion imparts a vibration to the framing of the building. For anthracite coal, the screens usually have an angle or pitch of from 1 in. to 2 in. per foot, the average being about 2 in. per foot. These screens are run at from 90 to 280 shakes per minute, the average being about 200 shakes per minute, or 100 revolutions per minute for the cam-shaft. The throw of the eccentric or cam varies from 2 in. to 5 in.



placed at a much steeper incline and are frequently so hung that they have a combined rocking and swinging motion. Shaking screens are rarely employed in concentrating works on account of the fact that revolving screens can be hung in the upper part of the mill where they will not interfere with ther machinery, and hence the greater space that they occupy is not bjectionable while they do the sizing satisfactorily without imparting jar o the structure.

The capacities of shaking screens operating on anthracite coal have been riven as follows. The parties giving these figures advise the use of 140 R. P. M.

or the cam-shaft.

For broken and egg coal, ‡ sq. ft. per ton for 10 hours.

For stove and chestnut coal, ‡ sq. ft. per ton for 10 hours.

For pea and buckwheat coal, ‡ sq. ft. for 10 hours.

For birdseye and rice, 1‡ sq. ft. per ton for 10 hours.

For sizing bituminous coal, inclined shaking screens are extensively used n certain sections, particularly in the Middle Western States. These screens n certain sections, particularly in the middle western States. These screens are given a shaking motion by means of cams and connecting-roots, which make from 60 to 100 strokes per minute, the speed varying according to the amount of moisture in the coal. The throw of the eccentric is about 6 in. These screens are 7 ft. wide and vary in length according to the conditions in the tipple, no standard having been adopted. The average inclination at which they are set is 14°, though this angle varies under different conditions from 12° to 15°. The capacity of these screens running under the conditions given above is given by one maker as 2,000 to 2,500 tons per day of 8 hours. In one test lasting 8 hours, 2,000 tons of coal were passed over screens having perforated plates of the following dimensions:

in one test lasting 8 hours, 2,000 tons of coal were passed over screens having perforated plates of the following dimensions:

56 sq. ft. with 4" perforations for making slack.
56 sq. ft. with 14" perforations for making pea coal.
28 sq. ft. with 24" perforations for making nut coal.
28 sq. ft. with 44" perforations for making egg coal.
Another maker uses, for taking pea and dust from nut, and nut from lump, 50 to 60 sq. ft. of surface for each size, and to handle 600 to 800 tons in 8 hours he uses a 44" trayel and 120 to 130 shakes per minute with the 8 hours he uses a 44" travel and 120 to 130 shakes per minute, with the screen at an inclination of 15°.

Size of Mesh.—The following perforations have been adopted by two of the largest anthracite coal companies as the dimensions for the holes in shaking screens to produce sizes equivalent to those produced by revolving screens:

MESH FOR SHAKING SCREENS.

Kind of Coal.	Lehigh Valley Coal Co.	Phila. & Coal &	Reading Iron Co.	Kind of Coal	
	Round.	Round.	Square.		
Steamboat Lump Broken Egg Stove Chestnut Pea Buckwheat Rice	41" 31" 24" 14" 14" 11"	54" 44" 34" 24" 14" 4" 4" 14" 4" 14"	5" 4" 22" 2" 18" 8" 4"	Steamboat. Large broken. Small broken. Egg. Stove. Chestnut. Pea. Buckwheat. Rice.	

Revolving Screens, or Trommels.—The screen is placed about the periphery of a cylinder or frustum of a cone. The material to be sized is introduced at one end; the small size passes through the screen, and the other size is discharged from the other end. If the form is cylindrical, it is necessary to place the supporting shaft on an incline so that the material will advance toward the discharge end. The inclination of the shaft determines the rapidity with which the material will be carried through the agreen. The advantage of the conical screen is that the chaft is borighted. The advantage of the conical screen is that the shaft is horizontal and hence the bearings are simpler. This a very decided advantage in many mills where the machinery must of necessity be crowded into a minimum space and be hard to get at.

Pentagonal screens, or screens having some other number of flat sides. are sometimes employed. These are run at a very much more rapid rate than circular screens, it being intended that the material shall be thrown or dashed against the screen surfaces to break it or to loosen adhering clay or dirt. The shaft is sometimes hollow, and streams of water from this

hollow shaft wash the material as it is being screened.

Revolving screens are frequently jacketed, that is, two or more screens are placed concentrically about the same shaft, the inmost one being the coarsest, and each succeeding screen serving to make additional separations. This method reduces the space necessary for a given amount of sizing machinery. In other cases, a long cylindrical screen has a coarse mesh near its discharge end and finer mesh near the entrance end, thus making two or more through products as well as the overproduct. The disadvantage of jacketed screens is that the necessarily slow speed of the inmost screen reduces the capacity of the entire combination, so that if rapid work is essential, it is better to use fairly large-diameter screens placed one after the other in place of jacketed screens. Another disadvantage is that, to renew the inner jackets, it is often necessary to remove the outer ones.

The disadvantages of having two or more sizes of wire cloth on one screen are that the fine-meshed screen near the head is worn out rapidly, as all the material both coarse and fine passes over it, while, when separate screens are employed, each screen has to deal only with its through or over sized

product, all coarser material having been removed.

Speed.—The periphery of a revolving screen should travel about 200 ft. per minute. In the case of very fine material, screens are sometimes run faster than this.

The following have been adopted as standard speeds for screens by one

of the largest anthracite coal companies:

SPEED OF SCREENS.

	Rev. per	Minute.	Rev. per	Minute.
Mud screens	•••••••	8.87	Big screens	8.52
			Pony screens	
Cast-iron scre	ens	11 25	Buckwheat screens	15.30

Duty of Anthracite Screens.—The following table gives the number of square feet of screen surface required for a given duty in the case of revolving screens working upon anthracite coal:

Egg coal,	1	ton	per	1	sq.	ft.	per	10	hours.
Stove coal.	1	ton	per	11	sq.	ft.	per	10	hours.
Chestnut coal,									hours.
Pea coal,	1	ton	per	2	'8q.	ſt.	per	10	hours.
Buckwheat coal,	1	ton	per	27	sq.	ft.	per	10	hours.
Rice coal,	1	ton	per	3‡	SQ.	ft.	per	10	hours.
Culm.	1	ton	per	5	Sa.	ft.	per	10	hours.

These figures may be reduced from 20% to 30% for very dry or wash coal. Revolving Screen Mesh for Anthracite.—A standard mesh for revolving screens for sizing anthracite coal was adopted some years ago, but it is only approximately adhered to and a considerable variation from the standard is found throughout the anthracite region.

The following are probably as nearly standard meshes for revolving screens for sizing anthracite coal as can be given:

	MESH FOR SIZING COAL.
Culm	passes through 💤" mesh.
Birdseye	passes over '' mesh, and through '' mesh.
Buckwheat	passes over 1" mesh, and through 1" mesh.
Pea	passes over \" mesh, and through \" mesh.
Chestnut	passes over ?" mesh, and through 1?" mesh.
Stove	passes over 14" mesh, and through 2" mesh.
Egg	passes over 2" mesh, and through 2\frac{1}{2}" mesh.
*Grate	passes over 2?" mesh, and out end of screen.
*Special grate	passes over 3" mesh, and out end of screen.

*Special steamboat passes over 3" bars, and through 6" bars.

Hydraulic Classifiers.—The separation of materials by this class of machinery depends upon the law of equally falling bodies, which may be stated as follows: Bodies falling free in a fluid, full at a speed proportional to their weight divided by the resistance. From this it will be seen that small masses of a heavy mineral will fall as rapidly as large masses of a light mineral, owing to the fact that the weight increases as the volume and the

^{*}These sizes and "lump" size are seldom made, and there is no uniformity whatever in the sizes called by these names.

resistance only as the area, so that if a quantity of galena and quartz of various sizes were introduced into water, it would settle into approximate expers, each composed of relatively large pieces of quartz and relatively simall pieces of galena. This same action would be true in the case of any

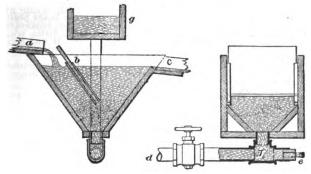


Fig. 17.

minerals differing in specific gravity. The principal representatives of the hydraulic classifying machines are the Spitzkasten and Spitzlutten.

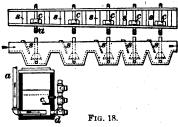
The Spitzkasten consists of a series of pyramidal boxes, one of which is shown in Fig. 17. The material enters the box at a, passes down under the diving board b, and discharges into the next box through the trough c. At the bottom of the box, water is introduced through the pipe d from the launder g in such quantity as to more than supply the opening or spigot c. The heavy particles of mineral settle against this rising stream of water into the elbow f, from which they are washed out through c. Each succeeding the stream of water and the stream of the box is made larger than the preceding, and the rising current is so regulated that a different product will settle out in each.

The Spitzlutten is a V-shaped box, inside of which is set another V having the same slope, the material flowing down between the two V's on one side and up and out on the other. The distance between the V's can be regulated, as can also the rising current of water, thus obtaining the separation desired.

Many other forms of separators, all depending on this same principle, have been brought out, some having a conical form, some being arranged in

the form of troughs, and others as boxes of various shapes.

The Calumet classifier, Fig. 18, consists of a series of boxes or pockets in the bottom of a gradually widening Wash water enters trough. through a pipe a and discharges directly against the discharge spigot d, which is however not large enough to carry all the water off directly, hence it twirls and eddies in the bottom of the box so that only the heaviest particles having weight enough to settle in this disturbed water pass out through the spigot. shield c reflects upward currents and confines the agitation to the bottom. The pulp flowing in the direction of the arrows is deflected downwards by the

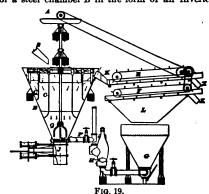


boards s. The settling boxes employed for mills are really a form of hydraulic classi-They are usually very large V-shaped boxes provided with a diving board similar to that shown at b in Fig. 17, but no current of water is

introduced. In some cases a small stream of the heavy muds or concer trates is kept continually flowing from the bottom, while in others the trates is kept continually nowing from the bottom, while in others the are drawn off intermittently. One very important point to be observed in settling boxes is that the settling action depends on the arresting the current, and with a given amount of floor space, very much most efficient settling can be obtained from two boxes placed side by side an having half the material pass through each than from two boxes placed in series, and that the width of the box is of vastly more important than the length. The depth is also fairly important, and a diving boar must always be introduced to prevent surface currents. If the boxe are properly arranged, nearly all the solid material will be settled out of the water. the water.

The Jeffrey-Robinson coal washer, Fig. 19, which operates on the principle of the Spitzkasten, consists of a steel chamber B in the form of an inverted

cone, inside of which are projecting arms and stirring plates C, C revolved by a driving gear A. The water supply enters at the bottom from the water pipe P through perforations M. The coal is introduced through a chute S and is kept in a continual state of agitation by the current of water, and being lighter than the impurities, it passes out through the overflow K onto the conveyors E, F and through the chutes X, X, while the water and sludge drain through the hopper into the sludge tank G, whence, if necessary, the same water can be again pumped by the pulsometer H back into the



washer. (As mentioned elsewhere, it is poor practice to use this water over again when it is desired to decrease the percentage of sulphur in the washed product as greatly as possible.)

The heavy impurities sink to the bottom into the chamber J and when this is full the upper of the two valves shown is closed and the lower valve is

opened to discharge the refuse.

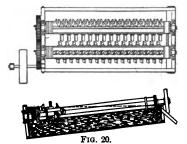
The following data in regard to one of these washers is given by Mr. J. J. Ormsbee in the Transactions of the A. I. M. E. These results were obtained at the Pratt Mines, Alabama, with a plant having a nominal capacity of 400 tons per day. By washing slack that passed between screen bars spaced \$\frac{1}{2}\$ in. in the clear, the washed coal contained 42% less sah than the unwashed coal, the reduction in sulphur was 15%, while the volatile matter was increased 44, and the fixed carbon 54. With coal passing over perforations, the results were a reduction of 48% in ash, 15% in sulphur, and a perforations, the results were a reduction of 48% in ash, 15% in sulphur, and a gain of 5% in volatile matter and 6% fixed carbon. These results indicate that the washer is better adapted to large sizes than to fines. The amount of water used per ton of washed coal was 35.1 gallons and the cost was 2.25 cents per ton for washing 400 tons, itemized as follows: Labor at washer. \$2.00; labor at boiler, fuel, etc., \$4.00; repairs and supplies, \$3.00; total, \$9.00. Log Washer.—For removing clay from ores or other material, the log washer illustrated in Fig. 20 has proved itself to be efficient. Either single or double logs are employed, the form shown being the double log washer. The logs work over troughs which have a slight inclination so that the water will flow from one end to the other. Water is introduced at the upper end and discharged at the lower end. The material to be washed

at the upper end and discharged at the lower end. The material to be washed is introduced near the lower end and is fed up against the water by spiral arms or plates fixed about the logs, as shown in the illustration. As the material is advanced the clay or other sticky substance is broken up, washed away, and discharged at the lower end with the wash water. These washers have been extensively employed for cleaning iron ores occurring as rather hard masses in clay.

There is no general standard size of these washers, but most of the doublelog washers for both steel and wood logs are the same, except in length of

logs, the washer box being 7 ft. 4 in. wide, 2 ft. deep at discharge end, and 4 ft. deep at receiving end. The length of logs varies from 20 to 30 ft. The logs are generally given an elevation of 1 in. in 1 ft., and sometimes 1; in. in 1 ft.

The capacity of an ore washer depends very much on the quality of the material, averaging for one pair of logs from 100 tons per day, when the matrix is of a clayey nature, to 550 tons with loose sandy material. The capacity of a washer is based on the amount of material from the mines it will put through more than the tonnage of clean ore, and this amount varies from



500 to 1,000 yd. per 10 hours. The amount of water used varies from 300 to 500 gal. per minute. The total expense for labor and fuel, including the water supply, varies from 5 cents to 25 cents per ton of ore, averaging

possibly 10 cents per ton.

The Seafe trough washer consists of a semicircular iron trough 2 ft. In diameter and 24 ft. long. Inside is a series of fixed dams or partitions that can be made higher or lower, as required, by means of plates. A shaft running the entire length of the trough and turning in babbitted journals carries a number of stirring arms or forks and is given a reciprocating motion by a connecting-rod attached to a driving pulley at its center. The coal is fed with water at the upper end of the trough, and by the action of the flowing water and the agitation of the arms, the slate, pyrites, and other impurities settle at the bottom and are caught behind the dams, while the clean coal passes over the dams and out at the lower end of the trough. When the spaces behind the dams are filled, feeding is stopped and the refuse in the dams quickly dumped. This form of washer is particularly successful with coal mixed with fireclay. One washer handles from 75 to 100 tons of coal per day, and one man can attend to six washers. Each washer requires less than 1 H. P. to operate it. The larger the coal, the greater must be the slope and the quantity of water used.

Jigs.—This is a general term applied to that class of concentrating machines in which the separation of the mineral from the gangue takes place on a screen or bed of material and is effected by pulsating up-and-

down currents of a fluid medium.

There are a number of different methods in use for driving the pistons are tause the pulsations of the water in jigs. Some of these use plain eccentrics, giving the same time to both the up and the down strokes of the pistons, while others employ special arrangements of parts, which give a quick down stroke and a slow up stroke, thus allowing the water ample time to work its way back through the bed without any sucking action from the piston. This tends to make a better separation in some cases than

the use of the plain eccentrics.

Stationary Screen Jigs.—This class is illustrated by Fig. 21, which shows a 3-compartment jig. The separation takes place on screens supported on wooden frames g, and is effected by moving the water in each compartment so that it ascends through the screen, lifting the mineral and allowing it to settle again, thus giving the material an opportunity to arrange itself according to the law of equally falling particles. Each compartment is composed of two separate parts, one containing the screen on the support g and the other adjoining it and arranged so that the piston in it may impart the necessary pulsations to the water. These pistons are usually loose fitting and are operated by the eccentries e on the shaft s. Jigs operating on coarse ore should be fed with approximately sized material, when the ore will accumulate near the bottom on the screen and the barren portion or gangue will

be carried over the discharge. Formerly, the concentrates were discharge from jigs intermittently by digging out the tailings first, then the middling which are composed of pieces containing some ore and some gangue, at then the concentrates, but it has been found that the concentrates will flow over the screen like a liquid of comparatively heavy specific gravity.

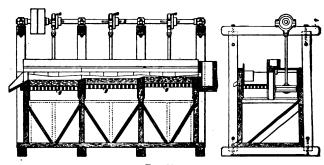
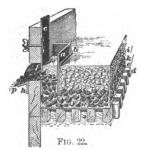


Fig. 21.

Advantage has been taken of this fact in the design of several forms of jig

discharges.

The Heberle gate, Fig. 22, acts as follows: a is a U-shaped shield fastened against the inside of the jig and held in place by a band b, the ends of which are drawn down into the form of the control of the sides of the



bolts and pass through the sides of the jig, where they are secured with suitable nuts. The shield a may be raised or lowered by loosening the band b. The discharge takes place through the opening f in the side of the jig, the size and position of the opening being regulated by slides c. The concentrates k rest on the screen e supported by a grating d, while the tailings i occupy a higher posi-tion. The shield a prevents the tailings from flowing out through the opening f. while the concentrates flow along the screen and rise to a height somewhat lower than the top of the tailings in the jig, when they are discharged through the

Fig. 22. opening f over the spout h, as shown at p. The tailings are usually discharged over the dam at the end of the jig, and in some cases a third discharge is provided of the Heberle-gate pattern and so arranged that the middlings will flow out through it and discharge the pattern and the form that silic and the content of the silic and the second that the middlings will flow out through it and discharge

separately from the tailings and the concentrates. In the case of jigs handling fine material, the material may be sorted by ydraulic classifiers and then introduced on to the jigs. In this class the mineral will be in the form of relatively small pieces, while the gangue will occur as relatively large pieces. Advantage may be taken of this fact by regulating the mesh of the jig screen so that the concentrates will pass through into the space below the screen, commonly called the hutch, will the tailings will pass over the tailing dam. In some cases the sate the tailings will pass over the tailing dam. In some cases the gate discharge is employed on the side to remove the middlings. The middlings are recrushed and treated on other machines. This form of concentration has been used very largely in connection with the Lake Superior copper ores, the values of which occur as metallic copper in a relatively light gangue, and also in concentrating tin ores that occur in the light gangue containing considerable mica.

Theory of Jigging.—By far the most exhaustive investigations on the theory Of jigging carried on in America are those of Prof. Robert H. Richards, of the Massachusetts institute of Technology, and the greater part of the following theoretical discussion is based on his several papers published in the Transactions of the American Institute of Mining Engineers.

Four laws of jigging are given by the several authorities: (1) The law of equal settling particles, under free settling conditions; (2) the law of interstitial currents, or settling under hindered settling conditions; (3) the

law of acceleration; (4) the law of suction.

The first of these is the most important, but the others are elements that cannot be disregarded in connection with jigging.

Equal Settling Particles.—Rittinger gives the following formulas to represent the relation between diameter of grains and rate of falling in water for irregularly shaped grains:

 $V = 2.73 \sqrt{D(\delta - 1)}$, for roundish grains;

 $V = 2.44 \sqrt{D(\delta - 1)}$, for average grains;

 $V = 2.37 \sqrt{D(\delta - 1)}$, for long grains;

 $V = 1.92 \sqrt{D(\delta - 1)}$, for flat grains

in which V = velocity in meters per second; D = diameter of particles in

meters, and δ = specific gravity of the minerals. By means of these different formulas, the ratios of the diameters of different particles that will be equal settling in water can be computed. Professor Richards has not found these formulas to hold in all cases in practice, and, as the result of elaborate experiments, he gives the following table:

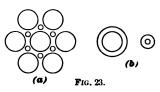
EQUAL SETTLING FACTORS OR MULTIPLIERS.

Table of equal settling factors or multipliers for obtaining the diameter of a quartz grain that will be equal settling under free settling conditions with the mineral specified.

	wity.	Velocity in Inches per Second.									82	
	Specific Gravity	1	2	3	4	5	6	7	8	9	Rittinger's	
	Spec		Author's Multipliers.									
Anthracite	1.473	.500									.2	
Epidote Sphalerite	3.380	1.57	1.35	1.05	1.13	1.50	1.61	1.56	1.56 1.66	1.47 1.56	1.4	
Pyrrhotite	4.046 4.508	1	$1.46 \\ 1.73$	$\frac{1.05}{1.29}$	1.17 1.48	1.62 2.00	1.64 2.22	1.68 2.26	2.13	2.08	2.1	
Chalcocite	5.334	İ	1.90	1.47	1.62	2.07	2.28	2.41	2.44	2.17	2.64	
Arsenopyrite	5.627			1.57	1.89	2.42	2.56	2.72	2.84	2.94	2.82	
Cassiterite	6.261		2.11	1.79	2.00	2.73	2.93	3.03	3.05	3.12	3.32	
Anitmony	6.706	į.	2.71	2.00	2.00	2.73	2.93	3.03	2.98	3.00	3.48	
Wolframite Galena	6.937 7.856	1	$\frac{2,71}{2.71}$	$1.83 \\ 1.83$	$\frac{2.07}{2.26}$	2.86 3.00	3.04	3.21	3.28 3.76	3.26 3.75	3.64 4.01	
Copper	8.479	İ	2.71	2.00	2.36	3.00	3.20	3.58	3.76	3.75	4.50	
Quartz	2.640	1 -			2.50	1 5.00	0.20	1 5.00				

The significance of the above table is as follows: If a piece of anthracite of a certain size falls in water with a velocity of 4 in. per second, a piece of quartz 0.213 times the diameter of the anthracite will fall with the same velocity. If a piece of quartz of a certain size falls with a velocity of 7 in. per second, a piece of copper 3.58 times as large as the quartz will fall with the same velocity.

Interstitial Currents, or Law of Settling Under Hindered Settling Conditions. If d equals the diameter of a falling particle, and D that of the tube in which it falls, the larger the fraction $\frac{a}{D}$, the greater will be the retardation or loss of velocity by the particle. When this fraction equals 1, the particle store If, in Fig. 23 (a), the larger circles represent particles of quartz and smaller circles equal settling particles of galena, then if these mixed particles are settling together or are held in suspension by a rising current water, each particle may be considered to be falling in a tube, the walks of which consist of the surrounding particles. Substituting a circle in each walks of the surrounding particles.



case for the imaginary tube, we have Fig. 23 (b) representing the conditions for galena and quartz, the outer circle in each case represent-Evidently, ing the imaginary tube.

is much smaller for the galens than for the quartz, and it will therefore be much less impeded in its fall than the quartz; hence, the

(a) Fig. 23.

The limit that the quarter indicates of galena found adjacent to the particles of galena found adjacent to the particles of quartz will be smaller than the ratio that the law of equal settling particles under free settling conditions would indicate. Application of this principle is found when a mass of grains is subjected to a rising current of sufficient force to rearrange the grains according to their settling power and the grains are said to be treated under hindered settling conditions, as on the bed of a lig. bed of a jig.

Interstitial factors, or multipliers for obtaining the diameter of the particle of quartz that under hindered settling conditions will be found adjacent to and in equilibrium with the particle of the mineral specified, are the

following:

Copper....... 8.598 Cassiterite 4.698 Pyrrhotite....... 2.808 Galena 5.842 Arsenopyrite ..3.737 Sphalerite 2.127 Wolframite...5.155 Chalcocite..... 3.115 Epidote1.628 Antimony ...4.897 Magnetite 2.808 Anthracite1782

These signify that, after pulsion has done its work on a jig bed, for example, where quartz and anthracite are being jigged, the grains will be so arranged that the grains of quartz are .1782 times the diameter of the grains of anthracite that are adjacent to and in equilibrium with them.

Acceleration.—A particle of galena that is equal settling to the particle of

quartz reaches its maximum velocity in perhaps, he time required by the quartz. The oft-repeated pulsations of a jig, therefore, give the galena particles a decided advantage over the quartz, placing beside the quartz, when equilibrium is reached, a much smaller particle of galena than we should expect according to the law of equal settling particles.

Suction acts to draw down through the screen small grains, mainly of the heavier mineral, which are distributed among large grains. It increases as the length of plunger stroke, with the difference in specific gravity of the two minerals, and with the diminishing of the thickness of the bed on the sieve, whether of the heavier mineral only or of both minerals. The law of suction seems to be that jigging is greatly hindered by strong suction where the two minerals are nearly of the same size, the quickest and best work then being done with no suction; but when the two minerals differ work then being done with no suction; but when the two minerals diner much in size of particles, the quartz being the larger, strong suction is not only a great advantage, but may be necessary to get any separation at all. Experiments have indicated an approximate boundary between grains that are helped and those that are hindered by suction; namely, if the diameter of the quartz particles is equal to or greater than 3.52 times the diameter of the other mineral particles, then separation is helped by suction; if less separation is hindered. This value 3.52 (obtained by dividing .0683 by .0195) is approximate only, and it will differ with the fracture of the quartz under consideration; if the quartz grains are much flattened, it will have a large value.

Eccentric jigs invariably spend more time on pulsion than accelerated jigs. Is it not fair to conclude that the eccentric jigs are better adapted for treating sands that require the most pulsion? Such sands are the sized products from the trommel and the first spigot of the hydraulic classifier. On the other hand, may not the long-protracted mild suction of the acceleration. ated jig be best adapted to the treatment of such products as require primary suction for their separation; for example, the second spigot and the following spigots of the hydraulic classifier? This may be the reason that the Collom jig has found so great favor at Lake Superior and at Anaconda, where all the jigging is done on true hydraulic-separator products, except the first sieve of the first jig. We should, however, bear in mind that the somewhat harsh suction of the eccentric jig can be made milder by increasing the hydraulic water. This will diminish the hardening of the bed, but it cannot lengthen the time of suction, so as to secure

the condition as presented in this particular by the accelerated jigs.

Two extreme suggestions arise from a contemplation of the experiments
we have carried on: (1) On closely sized products, an accelerated jig should be run backwards, to lengthen out the pulsion period, which is the only period that does any work; and (2) the accelerated jig should be run forwards on the spigot products of the hydraulic separator, to increase the

period of suction.

In the way of the first suggestion, there are two difficulties, either of which may cancel the advantage: first, the violent downward motion of the quick return will tend to "blind up" the sieve; and, second, the same action

will tend to pulverize a soft mineral like galena.

Professor Richards summarizes his experiments in connection with jigging as follows: The two chief reactions of jigging are pulsion and suction. The effect of pulsion depends on the laws of interstitial currents, or of equal settling particles, under hindered settling conditions. The chief function of pulsion is to save the larger grains of the heavier mineral, or the grains that settle faster and farther than the waste. The effect of suction depends on the interstitial factor of the minerals to be separated. If this factor is greater than 3.70, suction will be efficient and rapid. If the factor is less than 3.70, suction will be much hampered and hindered. The use of a long stroke will help to overcome this difficulty. The chief function of suction is to save the particles that are too small to be saved by the law of interstitial currents, acting through the pulsion of the jig. For jigging mixed sizes, pulsion with full suction should be used. For jigging closely sized products, pulsion with a minimum of suction should be used.

The degree of sizing needed as preparation for jigging, if perfect work is desired, depends on the interstitial factor of the minerals to be separated. If the factor is above 3.70 (assuming this value to be sufficiently proved), then sizing is simply a matter of convenience. The fine slimes should of course be removed; and if it is more convenient to send egg size, nut size, pea size, and sand size, each to its own jig, the suitable screens should be provided for this purpose and a hydraulic separator for grading the fines sizes. But if, on the other hand, the factor is below 3.70, then the jigging of mixed sizes cannot give perfectly clean work, and the separation will be approximate only. To effect the most perfect separation, close sizing must be adopted and the closer the sizes are to one another, the more rapid and perfect will the jigging be. There may be conditions where the jigging of mixed sizes of this class will be considered sufficiently satisfactory, as an

expedient, under the circumstances.

Removal of Sulphur From Coal.—The object of washing coal is to remove the slate and pyrites, thus reducing the amount of ash and sulphur. Many forms of washers easily and cheaply reduce the slate from 20% in the coal to 8% of ash in the coke, but it is much more difficult to reduce 4% of sulphur in the coal to 1% or less of sulphur in the coke. Sulphur occurs in the coal in three forms, as hydrogen sulphide, calcium sulphate, and pyrite. is volatile and is removed in coking, the second cannot usually be removed by preliminary treatment, and it is the removal of the third form with which washing has to do. The presence of water in the coke ovens apparently assists the removal of the sulphur; but wet coals require a longer time for coking than dry, and, therefore, pyrite should be removed as far as practicable before charging the coal into the coke ovens. The pyrite in coal as it comes from the mine seems to be in particles even finer than those of the coal dust. This impalpable powder or flour pyrites floats in air or water. This being the case, the common practice of using the water over and over again in a washery cannot give the best results in the removal of sulphur, as some flour pyrites will be carried back each time and remain with the washed coal. Experiments made by Mr. C. C. Upham, of New York City, show that the critical size at which an almost complete division of the coal and pyrites takes place varies with coals from different districts and beds, and in laying out coal-washing plants, the proper fineness of crushing should be determined beforehand by careful experiment.

Preparation of Anthracite.—The method of preparing anthracite coal is clearly shown, graphically, by the diagram below. This consists in screening the coal over bars and through revolving or over shaking screens, together with breaking it with rolls to produce the required market size.

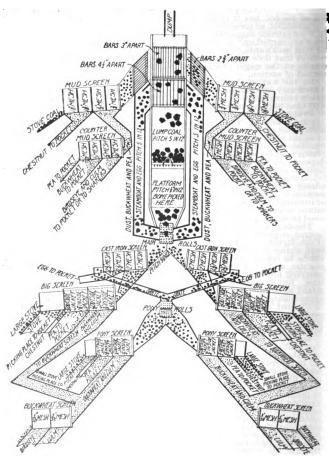


DIAGRAM SHOWING METHOD OF PREPARING ANTHRACITE COAL.

The large lumps of slate and other impurities are separated by hand on the platform near the dump, while the smaller portions are picked out by automatic pickers or by hand by boys or old men seated along the chutes leading to the shipping pockets or bins. The smaller sizes are cleaned by jigging.

HANDLING OF MATERIAL.

Anthracite Coal.—The following may be taken as average figures for the angle or grade of chutes for anthractic coal, to be used where the chutes are ined with sheet steel: For broken or egg coal, 2½ in. per ft.; for stove or chestnut coal, 3½ in. per ft.; for pea coal, 4½ in. per ft.; for buckwheat coal, 5 in. per ft.; for culm, 8 in. per ft.

If the coal is to start on the chute, 1 in. per ft. should be added to each of the coal of the coal is to start on the chute, 1 in. per ft. should be added to each of the coal

the above figures; while if the chutes are lined with manganese bronze in place of steel, the above figures can be reduced 1 in. per ft. for coal in motion, or would remain as in the table to start the coal. When the run of mine is to be handled, as in the main chute, at the head of the breaker, the angle should be not less than 5 in. per ft., or practically 22½° from the horizontal. If chutes for hard coal are lined with glass, the angle can be reduced from 30% to 50%, depending somewhat on the nature of the coal. In all cases, the flatter the coal, the steeper the angle must be, on account of the large friction surfaces exposed, compared with the weight of the piece. If chutes are lined with cast iron, the angle should be about the same as that employed for steel, though sometimes a slightly greater angle is allowed. The following table is printed through the courtesy of the Link-Belt Engineering Co., Philadelphia, Pa.:

PITCH AT WHICH ANTHRACITE COAL WILL RUN, IN INCHES PER FOOT.

-	Sheet	Iron.	Cast Iron.	Gla	3.88.	Glass.	
Kind of Coal.	Start on.	Con- tinue on.	Start on.	Start on.	Con- tinue on.	Start on.	Con- tinue on.
			Dry.			W	et.
Broken slate Dry egg slate Dry stove slate Dry stove slate Dry chestnut slate Broken coal Egg coal Chestnut coal Pea coal Buckwheat No.1 Buckwheat No.2 Buckwheat No.3 Buckwheat No.4 Buckwheat No.4	55444 5555 56 34454 56 4454	4 4 4 4 4 4 4 5	555555 Sheet of the 155555555 Sheet of the 1555555555555555555555555555555555555	31414145838 3223 3334444444 33344444444444444444	3 3 3 14 14 14 14 14 14 14 14 14 14 14 14 14	21 21 3 3 31 31 41 41 41	14 2 2 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4

Bituminous Coal —When the run of mine is to be handled, the angle of the chutes should be from 35° to 45° from the horizontal, or from 84 in. to 12 in. per ft. If the coal is wet, the angle should always be steeper, and coarse coal will slide on a flatter angle than slack or fine coal.

Ore, Rock, Etc.—For coarse fairly dry ore, i. e., from 2 in. or 3 in. size up, chutes may have an angle of 45°, or if the material is always to be in motion, the ore will sometimes slide on 40°. For fine ore or run of mine, the chutes should have an angle of 50° from the horizontal or practically 14 in. vertical

to 1 ft. horizontal.

Flumes and Launders.—Water flumes are given grades varying from 4 or 5 to 20 or 30 ft. per mile, depending on the surface of the ground and the amount of water to be carried. Practical results have demonstrated the fact that in ordinary ground the water should travel at the rate of from 180 to 200 ft. per

Where rather coarse stuff is to be carried through launders in a mill with a comparatively small amount of water, an angle of 2 in. per ft. should be used. With an excess of water, 1 in. per ft. will be ample. The spouting for vanners or launders from trommels carrying rather fine material should have a grade of about 2 in. per ft. In placer mining, the minimum grade for the sluice should not be less than \(\frac{1}{4}\) in. per ft., or about 4\(\frac{1}{4}\) in. per Experiments made in river gravel have shown that with a grade of from 20 to 1 in 25, 60 cu. ft. per min. will wash 140 to 175 cu. yd. per day of 24 in 25.

20 to 1 in 25, 60 cu. ft. per min, will was 140 to 15 cu. yd. per day of 24 h No absolutely definite figures can be given on this subject, owing t fact that the nature of the ore plays an important part, and while an quartzose ore can be transported at a comparatively flat angle, it m necessary to use quite a steep angle if the material is of a clayey nature contains many large flat plates, exposing large friction surfaces when pared to the mass of the pieces.

The following tables are printed through the courtesy of the Link

Engineering Co., Philadelphia, Pa.:

HORIZONTAL PRESSURE EXERTED BY BITUMINOUS COAL AGAINST VERTICAL
RETAINING WALLS PER FOOT OF LENGTH.



Surface horizontal { total pressure pressure lowest ft.	=	6.37 d2 6.37(2 d - 1)
Surface sloping { total pressure pressure lowest ft.	=	$10 d^2$ $10(2 d - 1)$
Angle of repose	_	35°

BITUMINOUS.

Horizo Surfa b m		ace.	ce. Surface.			Horizo Surfa b n	ice.	Surf	Sloping Surface. b e.	
Depth ba in	Total Pressure.	Pressure Lowest Ft.	Total Pressure.	Pressure Lowest Ft.	Depth bain	Total Pressure.	Pressure Lowest Ft.	Total Pressure.	Pressure Lowest Ft.	
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 12 22 23 24 24 25 26 26 27 28 28 29 29 20 20 20 20 20 20 20 20 20 20 20 20 20	6.4 25.0 57.0 102.0 159.0 229.0 312.0 407.0 516.0 917.0 1,076.0 1,433.0 1,630.0 2,063.0 2,298.0 2,809.0 3,083.0 3,369.0	6.4 19.0 32.0 45.0 70.0 83.0 96.0 108.0 121.0 134.0 146.0 172.0 185.0 197.0 223.0 226.0 2248.0 261.0 274.0 287.0	10 40 90 160 360 490 640 1,000 1,210 1,690 1,260 2,580 2,580 3,240 4,000 4,410 4,840 4,840 5,290	10 30 50 70 90 110 130 150 170 190 220 220 220 2270 290 330 350 350 370 390 410 450	26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48	4,305 4,641 4,993 5,753 6,122 6,523 6,525 7,378 8,253 8,764 9,193 9,682 10,192 10,692 11,296 11,296 11,298 13,478 14,179	325 338 350 363 376 389 401 414 427 440 452 465 478 503 516 529 541 557 589 592 606	6,760 7,290 7,840 8,410 9,000 9,610 10,290 11,550 12,250 12,250 13,660 14,440 15,210 16,810 17,640 19,350 21,160 22,030 21,160 22,030 21,160	510 530 550 570 590 610 630 650 670 690 710 730 750 770 7810 830 850 850 910 930	
24 25	3,669.0 3,981.0	299.0 312.0	5,760 6,250	470 490	49 50	15,275 15,925	618 631	24,010 25,000	970 990	

Weight of coal = 47 lb. per cu. ft.

RIZONTAL PRESSURE EXERTED BY ANTHRACITE COAL AGAINST VERTICAL RETAINING WALLS PER FOOT OF LENGTH.



!	Surface horizontal { total pressure pressure lowest ft.	==	$9.78 d^2$ $9.78(2 d - 1)$
	Surface sloping { total pressure pressure lowest ft.	==	$14.22 d^2$ $14.22(2 d - 1)$
_	Angle of repose	-2	270

ANTHRACITE.

				ANIII					
1 L	Horizo Surfa b n	ace.	Slop Surfi	ace.	in Ft.	Horizo Surfa b n	ace.	Suri	oing face. e .
Depth 6 a m	Total Pressure.	Pressure Lowest Ft.	Total Pressure.	Pressure Lowest Ft.	Depth bain	Total Pressure.	Pressure Lowest Ft.	Total Pressure.	Pressure Lowest Ft.
1 2 3 4	9.78 39.12 88.02	9.78 29.34 48.90	14.22 56.88 127.98	14.22 42.66 71.10	26 27 28	6,611.1 7,129.5 7,667.6	498.78 518.35 537.90	9,612.8 10,366.0 11,149.0	725.21 753.67 782.10
5	156.48 244.50	68.46 88.02	227.52 355.50	99.54 127.98	29 30	8,225.0 8,802.0	557.46 577.01	11,988.0 12,797.0	810.54 839.00
5 6 7	352.08	107.58	511.92	156.42	31	9,398.5	596.59	13,665.0	867.41
7	479.22	127.14	696.78	184.86	32	10,015.0	616.14	14,561.0	895.86
8	625.92	146.70	910.08	213.30	33	10,650.0	635.70	15,486.0	924.30
9	792.18	166.26 185.82	1,151.82 1,422.00	$241.74 \\ 270.18$	34 35	11,306.0 11,980.0	655.26 674.81	16,439.0 17,420.0	952.70 981.19
10	978.00 1,183.38	205.38	1,720.62	298.62	36	12,675.0	694.39	18,429.0	1.009.60
12	1,408.32	224.94	2.047.68	327.06	37	13,389.0	713.94	19,467.0	1,009.00
13	1,652.82	244.50	2,403.18	355.50	38	14,123.0	733.50	20,533.0	1,066.50
14	1,916.88	264.06	2,787.12	383.94	39	14,875.0	753.07	21,629.0	1,095.00
15	2,200.50	283.62	3,199.50	412.38	40	15,648.0	772.63	22,752.0	1,123.40
16	2,503.68	303.18	3,640.32	440.82	41	16,440.0	792.20	23,904.0	1,151.80
17	2,826.42	322.74	4,109.56	469.26	42	17,252.0	811.74	25,084.0	1,180.30
18	3,168.72	342.30	4,607.28	497.70	43	18,083.0	830.73	26,293.0	1,208.70
19	3,530.58	361.86	5,133.42	526,14	44	18,934.0	850.86	27,530.0	1,237.20
20 21	3,912.00	381.42	5,688.00	554.58	45	19,804.0	870.41	28,793.0	1,265.60
21	4,313.00	400.98	6,271.00	583.26	46	20,695.0	889.99	30,090.0	1,294.00
22	4,733.50	420.54	6,882.50	611.46	47	21,605.0	909.54	31,412.0	1,322.30
22 23 24 25	5,173.70	440.10	7,522.50	639.90	48	22,533.0	929.10	32,763.0	1,350.90
24	5,633,30	459.67	8,190.70	668.35	49	23,482.0	948.66	34,143.0	1,379.40
25	6,112.60	479.22	8,887.50	696.79	50	24,450.0	968.21	35,550.0	1,407.90

HORSEPOWERS FOR COAL CONVEYORS (COAL INCLUDED).

Speed, 100 ft. per minute. Conveyors, 100 ft. long. Standard steel troughs.

		Horiz	ontal.	Inclined.	اوة		Horiz	ontal.	Inclined.
Size of Chain.	Size of Flights. In.	12 In. Between Flights.	18 In. Between Flights.	12 In. Between Flights.	Size o	Size of Flights. In.	16 In. Between Flights.	24 In. Between Flights.	16 In. Between Flights.
tin. or tin. Dodge.	4×10 4×12 5×12 5×15 6×18	2½ 3 3½ 4½ 5½	2 21 3 3 31 41	3 31 4 51 61	in. Dodge.	5 × 15 6 × 18 8 × 18 8 × 20 8 × 24 10 × 24	4 5 7 8 91 121	3½ 4 5 6 7 8	41 51 8 10 111 14

WEIGHTS AND CAPACITIES OF STANDARD STEEL BUCKETS.

ė	Size of Bucket,	Weight of	Capacity of	Capacity of Elev	ator. 100' per Min.	84
Chain.	In. Buck		Bucket. Lb.	Lb. per Min.	Net Tons per Hr.	A N
% In. Dodge.	$12 \times 9 \times 111$ $14 \times 9 \times 111$ $18 \times 9 \times 111$ $24 \times 9 \times 111$	181 221 27 36	11 12¼ 16¼ 22	1,100 1,250 1,650 2,200	33.0 37.5 49.5 66.0	5,35 5,35 5,35 5,35
1 In. Dodge.	$\begin{array}{c} 12\times10\times16\frac{1}{4} \\ 18\times10\times16\frac{1}{4} \\ 24\times10\times16\frac{1}{4} \\ 30\times10\times16\frac{1}{4} \\ 18\times12\times16\frac{1}{4} \\ 24\times12\times16\frac{1}{4} \\ 30\times12\times16\frac{1}{4} \end{array}$	20 29 38 461 31 40 48	19 281 38 471 33 44 55	1,380 2,072 2,760 3,450 2,400 3,200 4,000	41.4 62.2 82.8 103.5 72.0 96.0 120.0	5,33 5,33 5,33 5,33 5,33 5,33

Buckets taken # full. Buckets continuous. 1 lb. of coal = 34 cu. in. ELEVATING CAPACITIES OF MALLEABLE IRON BUCKETS.

Table gives tons (2,000 lb.) of pea coal per hour at 100 ft. per minute.

Bucket	ts.	Capa	cities.		Dis	ance	Betv	veen	Buck	ets in	In.	
Size. In.	Wt. Lb.	Cu. In.	Lb.	8	10	12	14	16	18	20	22	24
$\begin{array}{c} 2\frac{3}{4} \times 4 \\ 3\frac{1}{4} \times 5 \\ 4 \times 6 \\ 4\frac{1}{4} \times 7 \\ 5 \times 8 \\ 6 \times 10 \\ 7 \times 12 \\ 7 \times 14 \\ 10 \times 18 \end{array}$	0.75 1.50 2.00 2.56 3.56 5.47 8.97 11.41	15 31 51 75 102 185 287 295	0.48 0.97 1.57 2.33 3.15 5.73 8.90 9.14	2.16 4.36 7.06 10.38	5.65 8.39 11.34	2.91 4.71 6.99	8.10 14.73 22.88	2.18 3.53 5.19 7.09 12.88 20.02	1.94 3.14 4.66 6.30 11.46 17.80	2.83 4.19 5.67 10.31	5,15 9,38 14,56	

Weight of 1 cu. ft. of pea coal = 53.5 lb. 32.3 cu. in., or .0187 cu; ft. CONVEYING CAPACITIES OF FLIGHTS AT 100 FT. PER MINUTE.

(Tons of Pea Coal per Hour.)

		Horiz	ontal.			Inclined	
Size of					10°	Every 24 In.	30°
Flight. In.	Every 16 In.	Every 18 In.	Every 24 In.	Lb.Coal per Flight.	Every 24 In.		Every 24 In.
4 × 10 4 × 12 5 × 15 6 × 18 8 × 18 8 × 20 8 × 24 10 × 24	33.75 42.75 51.75 69.75	30 38 46 62 80 120	22.5 28.5 34.5 46.5 60.0 90.0 105.0 135.0 172.5	15 19 23 31 40 60 70 90	18.0 24.0 28.5 40.5 49.5 72.0 84.0 120.0 150.0	14.25 18.00 22.50 31.50 40.50 57.00 66.50 96.00 120.00	10.5 13.5 16.5 22.5 31.5 48.0 56.0 72.0 90.0

Note.—These ratings are for continuous feed. 2,000 lb. = 1 ton.

HORSEPOWER FOR BUCKET ELEVATORS.

$$H. P. = N \times \frac{H\omega}{d}.$$

N = number taken from table:

H = height of elevator in feet;

ω = weight of material in one bucket: d =distance apart of buckets, in inches.

Revolu- tions			Revolu-				
per linute.	22 In.	24 In.	26 In.	28 In.	30 In.	32 In.	per Minute.
10 12 14 16 18 20 22 24 26 28 30 32 34 36 38	.064 .077 .089 .102 .115 .128 .140 .153 .166 .179 .191 .204 .217	.070 .083 .096 .111 .125 .139 .153 .167 .181 .195 .209 .223 .237	.075 .090 .106 .121 .136 .151 .166 .181 .196 .211 .226 .241 .256	.080 .097 .114 .130 .146 .162 .179 .195 .211 .227 .244 .260 .276	.087 .104 .121 .140 .157 .174 .191 .209 .226 .244 .261 .278 .296 .313	.093 .111 .130 .148 .167 .186 .204 .223 .242 .260 .279 .297 .316 .334	10 12 14 16 18 20 22 24 26 28 30 32 32
40	.242 .255	.265 .279	.287 .302	.309 .325	.331 .348	.353 .372	38 40

COST OF UNLOADING CCAL.

Coal is generally unloaded from railroad cars into the hold of a vessel by some form of unloader, which usually raises the car bodily and dumps it directly into the hold of the vessel. In this way the cost of unloading has been reduced to a very small figure, and the speed of unloading greatly The cost of unloading is given by the makers of the Brown hoist as varying from 21 cents per ton up to 41 cents per ton; deducting in each case 2 cents for trimming the coal in the vessel, the actual cost of loading varies from ‡ cent to 2½ cents per ton, depending on the conditions. Along the Lakes it is customary to pay a premium of ‡ cent per ton to all connected with the loading, for all coal loaded in excess of 2,500 tons per day and 1,800 tons per night. The Brown hoist has a guaranteed capacity of at least 300 tons per hour but this has been exceeded. tons per hour, but this has been greatly exceeded in practice. The McMyler end dump has a record of 4.65 tons per minute, and the McMyler side dump of 8.41 tons per minute. These figures apply to the lake cities of the United (See "Mines and Minerals," May, 1898, for complete description of States. coal-unloading machines.)

The C. W. Hunt Co., West New Brighton, New York, gives the following figures for handling coal along the Atlantic seaboard: The cost of shoveling coal by hand in the hold of the vessel into ordinary iron buckets is about 6 to 7 cents per ton of 2,000 lb.; the cost for iron ore, phosphate rock, or sand, about 10% less. The cost of shoveling coal and hoisting it out of vessel to the wharf with an ordinary hoist with manila rope is 12 to 13 cents per ton, so that the hoisting costs about the same as the shoveling. The cost for both shoveling and hoisting with a steam engine is 10 to 11 cents per ton. cost when using a steam shovel or grab bucket for taking up coal out of the vessel varies greatly in different classes of vessels, but usually runs from about 1½ to 5 cents per ton, averaging about 3 cents. After the coal is hoisted, it can be carried into storage with an automatic railway or other efficient plant, at a cost of about 1 to 1½ cents per ton. In places where the distance is great, a cable railway or a conveyor can be used, which handles the material about as cheaply as for short distances, but the cost of the plant is greatly increased.

The cost of stocking and unloading anthracite by the Dodge system given by Mr. Piez, "Mines and Minerals," June, 1898, page 488, as follows

Year.	Engine Service, Stocking and Lifting, per Ton. Cents.	Office Expense, per Ton. Cents.	Steam, Wages and Fuel, per Ton. Cents.	Labor, Dumping and Lifting, per Ton. Cents.	Repairs, per Ton. Cents,	Supplies, per Ton. Cents,	Total, per Ton.
1895	.87	.29	.97	2.67	.78	.25	5.83
1896	.78	.30	.82	2.19	.90	.27	5.26
1897	.69	.32	.62	1.88	.97	.16	4.64

BRIQUETING.

Machines Employed.—Fuel, fuel dust, and other products may be briqueted by a number of different styles of machines, but all these may be divided into two classes, briquet and eggette machines. The eggette machines have a pair of rollers, the faces of which are provided with semispherical or semi-ovoid openings. The material that is fed between these rolls crowds into the openings of the two rolls, thus forming small spheres. The material is mixed with a suitable bond before being fed to the rolls, and the eggettes are received on any suitable form of traveling belt or chute and removed for drying or storage. This style of machine has not been used to any great extent in this country. The briqueting machines all act more or less on the principle of the brick machine, having some kind of a die or mold into which the material is crowded. The material is either pressed as it is being fed into the mold or subsequently by some form of plunger. For some materials, common brick machines, such as are used in the manufacture of building brick, are employed, while in others special forms are necessary.

Briqueting of Fuel.—Fuel briquets have not come into general use in the United States for two reasons: (1) on account of the great amount of cheap fuel available, which has prevented the utilization of culm, coal dust, etc.: and (2) on account of the lack of or high price of suitable bonding material. This latter condition is now being removed by the introduction of by-product coke ovens, from which supplies of coal tar can be obtained. Aside from peat and certain kinds of brown coal, and possibly some caking coals, it is necessary to employ a bond in the making of any fuel briquets. This is especially true in the case of anthracite coal The present tendency is to employ no inorganic bonding materials, as they increase the ash. The material to be briqueted should be as clean and free from dirt or slate as possible, and the particles should be of practically uniform size, the most satisfactory product being from coal crushed to about $\frac{1}{4}$ in. cube size. The coal must be thoroughly mixed with bonding material and then subjected to a heavy pressure. One advantage claimed for briquets is that they can be made of such a form as to occupy less space than the original fuel. The French navy has found it possible to store 10% more briquets than coal in a given space, and also that the loss by breakage and pulverization is very much less. Under favorable conditions, fuel can be briqueted for 20 cents per ton, and the following are some of the advantages claimed for these briquets: They are sound throughout and will not decrepitate while burning, thus reducing the loss by fine material working through the grates. The bond, if properly selected, renders the briquets practically waterproof, so that they are not injured if kept in storage, do not evolve combustible gases, nor ignite from spontaneous combustion. There is no fine material mixed with the briquets, and hence a more uniform fire can be maintained with them.

Briqueting of flue Oust.—Flue dust from iron blast furnaces has been successfully briqueted in a number of instances. One firm employs a common brick machine, making bricks $2\frac{1}{4}$ in. \times 4 $\frac{1}{4}$ in. \times 9 in. With this machine, they mix the flue dust with 3% of lime and 3% of cement, the lime acting as a flux in the furnace. These machines work with comparatively light pressure. When regular briqueting machines, producing round bricks and

ploying high pressures are employed, no cement need be used, the flue dust eing mixed with 4% to 6% lime. The flue dust is first carefully screened from eard lumps and then mixed warm with milk of lime in a mixer, after r hich it is put through the press, and the briquets are then placed in drying

vens and subjected to heat from the gases of a boiler or furnace plant, he temperature not to exceed 300° F. For moderate sized briquets, about hours' drying is sufficient. Just before the briquets are quite dry, they re loaded into barrels and taken direct to the blast furnace, with as ittle handling as possible. The results have been very satisfactory compared with the ore replaced. The flue dust itself frequently contains 30% to 40% and 100 members are subjected by the contains 30% to 40% and 100 members. n etallic iron and more or less carbonaceous matter. It is also stated that at large furnace plant the cost of making and handling should not exceed 51 per ton.

Another firm, figuring on a basis of 130 tons per 24 hours, and using 36

time in the solution, gave the following figures:

4 tons lime, \$3.00 per ton	\$ 12.00	
2 machine tenders (day and night), 12 hours, at \$2.50 2 laborers (day and night), 12 hours, at \$1.75	5.00	
2 laborers (day and night), 12 hours, at \$1.75	8.50	
Oil and waste	2.00	
Wear on machinery		
Interest on cost of plant	1.00 \$	25.00

This is less than 20 cents per ton. This estimate does not take into consideration the cost of power, which would be about 35 H. P., nor does it take into consideration hauling of material to plant and removing of briquets.

CUBIC FEET OCCUPIED BY 2.000 POUNDS OF VARIOUS COALS.

(Link-Belt Engineering Co., Philadelphia, Pa.)

Varieties.	E	Broken.	Egg.	Stove.	Chestnut.	Pea.
Lackawanna, anthracite		37.10	36.65	34.90	34.35	37.25
Garfield red ash, anthracite		37.30	36.95	36.35	36.35	37.50
Lykens Valley, anthracite		37.55	37.25	37.55	37.25	38.50
Shamokin, anthracite	-	38.05	37.70	37.25	37.25	38.50
Plymouth red ash, anthracite		34.90	34.85	34.75	34.70	36.90
Wilkes-Barre, anthracite		34.95	34.35	33.75	34.00	36.90
Lehigh, anthracite		33.30	33.80	33.55	32.55	33.05
Lorberry, anthracite		34.65	34.20	33.80	33.55	35.20
Scranton, anthracite		35.35	35.20	34.60	33.30	34.95
Pittston, anthracite		35.45	34.95	34.35	33.70	35.50
	6.65		ontas,	bitumi	nous	34.00
Clearfield, bituminous 3	3.55				oituminous	41.50
New River, bituminous 4	0.15	Englis	h can	nel, bit	uminous	42.30

TREATMENT OF INJURED PERSONS.

The dangers to be feared in case of wounds, are: shock or collapse, loss of

blood, and unnecessary suffering in the moving of the patient.

In shock, the injured person lies pale, faint, and cold, sometimes insensible, with feeble pulse and superficial breathing. The cause of death in The cause of death in case of a shock is arrest of heart action, produced by the suspension of the functions of the brain and spinal cord. In treatment, the two most important parts are: (1) the position of the injured person; (2) the application of external warmth.

The injured person should at once be placed in a recumbent position, his head resting on a plane lower than that of his trunk, legs, and feet. should be well wrapped up and protected from the chilling influences of external air. When there is danger of immediate death, stimulants should be given; in all other conditions of shock, stimulants are injurious.

Loss of Blood.—In case of loss of blood, two conditions present themselves:

(1) The bleeding is arrested spontaneously or otherwise, but the injured person presents all the symptoms of loss of blood; (2) the injured person is actually bleeding, and he is, or is not, suffering from loss of blood. In the first condition, life is threatened by anemia of brain and spinal cord, and all the efforts of treatment are to direct the flow of whatever

quantity of blood may still remain in the body to the vital centers in brain and spinal cord. This is most efficiently done by placing the inju person in a recumbent position, with his head resting on a plane some





lower than that of his trunk and legs. In graver cases, constricting bands should be applied to both arms, as near the shoulders as possible, and to both thighs, as near the abdomen as possible. This last maneuver directs the entire quantity of blood in the body to the suffering centers, the centers of life itself. Stimulation the body to the suffering centers, the centers of the suffering centers of the suffering centers.

of life itself. Stimulants may be sparingly administered. If there is bleeding, do not try to stop it by binding up the wound. The current of blood to the part must be checked. To do this, find the artery, by its beating; lay a firm and even compress or pad (made of cloth or rags rolled up, or a round stone or piece of wood well wrapped) over the artery (Fig. 1). The a handkerchief around the limb and compress; put a

bit of stick through the handkerchief and twist the latter up

until it is just tight enough to stop the bleeding; then put one end of the stick under the handkerchief, to prevent untwisting, as in Fig. 2.

The artery in the thigh runs along the inner side of the muscle in front near the bone, as shown by dotted line in Fig. 3. A little above the knee it passes to the back of the bone. In injuries at or above the knee, apply the compress higher up. on the inner side of the thigh, at the point P, Fig. 3, with the knot on the outside of

the thigh. When the leg is injured below the knee, apply the compress at the back of

the thigh, just above the knee, at P, Fig. 4, and the knot in front, as in Figs. 1 and 2. F1G. 4.



Fig. 3.



Fig. 5.



FIG. 6.

pillows, laid on a board with side pieces of board nailed on, when this can be done. If possible, let the patient be laid on a door, shutter, settee, or some firm support, properly covered. Have sufficient force to lift him steadily, and let those that bear him not keep step.

Should any important arteries be opened, apply the handkerchief, as recommended. Secure the vessel by a surgeon's dressing forceps, or by a

Proof. then have a silk ligature put around the vessel, and tighten. Should the bleeding be from arterial vessels of small size, apply persulphate of iron, either in tincture or in powder, by wetting a piece of lint or sponge with the solution; then, after bleeding ceases, apply a compress against the parts, to soustain them during the application of the persulphate of iron, and to prevent further bleeding, should it occur. The persulphate of iron should be

Bleeding From Seelp Wounds.—A pad or compress is placed immediately before the ear, over the region marked by a dotted line, Fig. 6. The compress is firmly secured by a handkerchief. If this does not arrest bleeding, a similar compress on the opposite side should be applied. Should the bleed-ing issue from a wound of the posterior or back part of the head, a compress should be placed behind the ear, over the region marked by the dotted line,

Fig. 6, and firmly secured by a handkerchief or bandage.

TREATMENT OF PERSONS OVERCOME BY GAS.

Miners are exposed to asphyxia when the circulation of the air is not sufficiently active, when the mine exhales a quantity of deleterious gas, when they imprudently penetrate into old and abandoned workings, and when there is an explosion.

The symptoms of asphyxia are sudden cessation of the respiration, of the pulsations of the heart, and of the action of the senses; the countenance is swollen and marked with reddish spots, the eyes are protruded, the features

are distorted, and the face is often livid, etc.

kept in or about all working places.

The best and first remedy to employ, and in which the greatest confidence ought to be placed, is the renewal of the air necessary for respiration. Proceed as follows:

1. Promptly withdraw the asphyxiated person from the deleterious place

and expose him to pure air.

Loosen the clothes round the neck and chest, and dash cold water

in the face and on the chest.

Attempts should be made to irritate the mucous membrane with the feathered end of a quill, which should be gently moved in the nostrils of the insensible person, or to stimulate it with a bottle of volatile alkali placed under the nose.

Keep up the warmth of the body, and apply mustard plasters over the heart and around the ankles.

If these means fail to produce respiration, Doctor Sylvester's method

of producing artificial respiration should be tried as follows:

Place the patient on the back on a flat surface, inclined a little upwards from the feet; raise and support the head and shoulders on a small firm cushion or folded article of dress placed under the shoulder blades. Draw forwards the patient's tongue and keep it projecting beyond the lips; and lastic band over the tongue and under the chin will answer this purpose, or a piece of string or tape may be tied around them, or by raising the lower a piece or string or tape may be used around them, or by raising the lower jaw the teeth may be made to retain the tongue in that position. Remove all tight clothing from about the neck and chest, especially the suspenders. Then standing at the patient's head, grasp the arms just above the elbows, and draw the arms gently and steadily upwards above the head, and keep them stretched upwards for 2 seconds (by this means air is drawn into the lungs). Then turn down the patient's arms and press them gently and firmly for 2 seconds against the sides of the chest (by this means air is pressed out of the lungs). Beneat these meanures literately deliberately. out of the lungs). Repeat these measures alternately, deliberately, and perseveringly about 15 times in a minute, until a spontaneous effort to respire is perceived, immediately upon which cease to imitate the movements of breathing, and proceed to induce circulation and warmth.

To promote warmth and circulation, rub the limbs upwards with firm, grasping pressure and energy, using handkerchiefs, flannels, etc. Apply hot flannels, bottles of hot water, heated bricks, etc. to the pit of the stomach,

the arm pits, between the thighs, and to the soles of the feet.
7. On the restoration of life, a teaspoonful of warm water should be given, and then, if the power of swallowing has returned, small quantities of wine,

warm brandy and water, or coffee should be administered.

These remedies should be promptly applied, and as death does not certainly appear for a long time, they ought only to be discontinued when it is clearly confirmed. Absence of the pulsation of the heart is not a sure sign of death, neither is the want of respiration.

COAL DEALERS' COMPUTING TABLE, FOR ASCERTAINING THE PRICE OF ANY NUMBER OF POUNDS, AT A GIVEN PRICE PER TON OF 2,000 POUNDS.

Lb.	\$ 0.75	\$ 1.00	\$1.25	\$1. 50	\$ 1.75	\$2.00	\$2.25	\$2.50	\$2.75
10	.01	.01	.01	.01	.01	.01	.01	.01	.01
20	.01	.01	.01	.02	.02	.02	.02 .03	.03	.03
30	.01	.02	.02	.02	.03	.03	.03	.04	.04
40	.02	.02	.03	.03	.04	.04	.04	.05	.06
50	.02	.02	.03	.04	.04	.05	.06 .07	.06	.07 .08
60 70	.02 .03	.03 .03	.04 .04	.05 .05	.05 .06	.06 .07	.07	.08 .09	.10
80	.03	.03	.05	.00	.07	.08	.09	.10	.11
90	.03	.04	.06	.06 .07	.08	.09	.10	.11	.12
100	.04	.05	.06	.08	.09	.10	.11	.13	.14
200	.08	.10	.13	.15	.17	.20	.23	.25	.28
300	.11	.15 .20	.19	.23	.26	.30	.34	.38 .50	.41
400	.15	.20	.25	.30	.35	.40	.45	.50	.55
500	.19	.25	.31	.38	.44	.50	.56	.63	.69
600 700	.23 .26	.30 .35	.37 .44	.45 .53	.53 .61	.60 .70	.68 .77	.75	.83 .96
800	.30	.40	.50	.60	.70	.80	.90	.88 1.00	1.10
900	.34	.45	.56	.68	.79	.90	1.01	1.13	1.10
1,000	.38	.50	.63	.75	.88	1.00	1.13	1.25	1.38
1.100	.41	.55	.69	.83	.96	1.00 1.10	1.13 1.24	1.25 1.38	1.24 1.38 1.51
1,200	.45	.60	.75	.90	1.05	1.20	1.35	1.50 1.63 1.75	1.65
1,300	.49	.65	.81	.98	1.14	1.30	1.46	1.63	1.79
1,400	.52	.70	.88	1.05	1.22	1.40	1.58 1.69	1.75	1.93
1,500	.56 .60	.75 .80	.94 1.00	1.13	1.31 1.40	1.50 1.60	1.69	1.88 2.00	2.06 2.20
1,600 1,700	.64	.85	1.06	1.20 1.28	1.40	1.70	1.80 1.91	2.13	2.34
1,800	.68	.90	1.13	1.35	1.58	1.80	2.03	2.25	2.48
1,900	.71	.95	1.19	1.43	1.66	1.90	2.14	2.38	2.61
	\$3.00					•	\$4.50	\$4.75	\$5.00
Lb.	\$3.00	\$3.25	\$3.50	\$ 3.75	\$4.00	\$4.25	\$ 4.50	\$4.75	\$5.00
Lb.	.02	\$3.25	\$3.50	\$3.75	\$4.00 .02	\$4.25 .02	- 03	.03	.03
Lb.	.02	\$3.25 .02 .03	\$3.50 .02 .04	\$3.75 .02 .04	\$4.00 .02	\$4.25 .02 .05	- 03	.03 .05	.03
Lb.	.02 .03 .05	\$3.25 .02 .03	\$3.50 .02 .04 .05	\$3.75 .02 .04 .06	.02 .04 .06	.02 .05 .07	.03 .05 .07	.03 .05 .07	.03 .05
Lb. 10 20 30 40	.02 .03 .05 .06	.02 .03 .05 .07	.02 .04 .05 .07	\$3.75 .02 .04 .06 .08	.02 .04 .06 .08	.02 .05 .07 .09	.03 .05 .07 .09	.03 .05 .07 .10	.03 .05 .08
Lb.	.02 .03 .05 .06	\$3.25 .02 .03	\$3.50 .02 .04 .05	\$3.75 .02 .04 .06	.02 .04 .06	.02 .05 .07	.03 .05 .07	.03 .05 .07	.03 .05
Lb. 10 20 30 40 50 60 70	.02 .03 .05 .06 .08 .09	.02 .03 .05 .07 .08 .10	.02 .04 .05 .07 .09 .11	.02 .04 .06 .08 .09 .11	.02 .04 .06 .08 .10 .12	.02 .05 .07 .09 .11 .13	.03 .05 .07 .09 .12 .14	.03 .05 .07 .10 .12 .15	.03 .05 .08 .10 .13 .15
Lb. 10 20 30 40 50 60 70 80	.02 .03 .05 .06 .08 .09 .11	.02 .03 .05 .07 .08 .10 .11	.02 .04 .05 .07 .09 .11 .12	.02 .04 .06 .08 .09 .11 .13	.02 .04 .06 .08 .10 .12 .14	.02 .05 .07 .09 .11 .13 .15	.03 .05 .07 .09 .12 .14 .16	.03 .05 .07 .10 .12 .15 .17	.03 .05 .08 .10 .13 .15
Lb. 10 20 30 40 50 60 70 80 90	.02 .03 .05 .06 .08 .09 .11 .12	.02 .03 .05 .07 .08 .10 .11 .13	.02 .04 .05 .07 .09 .11 .12 .14	.02 .04 .06 .08 .09 .11 .13 .15	.02 .04 .06 .08 .10 .12 .14 .16	.02 .05 .07 .09 .11 .13 .15	.03 .05 .07 .09 .12 .14 .16 .18	.03 .05 .07 .10 .12 .15 .17 .19	.03 .05 .08 .10 .13 .15 .18 .20
Lb. 10 20 30 40 50 60 70 80 90 100	.02 .03 .05 .06 .08 .09 .11 .12 .14	.02 .03 .05 .07 .08 .10 .11 .13 .15	.02 .04 .05 .07 .09 .11 .12 .14 .16	.02 .04 .06 .08 .09 .11 .13 .15 .17	.02 .04 .06 .08 .10 .12 .14 .16 .18	.02 .05 .07 .09 .11 .13 .15 .17 .19	.03 .05 .07 .09 .12 .14 .16 .18 .20	.03 .05 .07 .10 .12 .15 .17 .19 .22	.03 .05 .08 .10 .13 .15 .18 .20
Lb. 10 20 30 40 50 60 70 80 90 100 200	.02 .03 .05 .06 .08 .09 .11 .12 .14 .15	.02 .03 .05 .07 .08 .10 .11 .13 .15 .16	.02 .04 .05 .07 .09 .11 .12 .14 .16 .18	\$3.75 .02 .04 .06 .08 .09 .11 .13 .15 .17 .19	.02 .04 .06 .08 .10 .12 .14 .16 .18 .20	.02 .05 .07 .09 .11 .13 .15 .17 .19 .22	.03 .05 .07 .09 .12 .14 .16 .18 .20 .23	.03 .05 .07 .10 .12 .15 .17 .19 .22 .24	.03 .05 .08 .10 .13 .15 .18 .20
Lb. 10 20 30 40 50 60 70 80 90 100 200 300	.02 .03 .05 .06 .08 .09 .11 .12 .14 .15 .30	.02 .03 .05 .07 .08 .10 .11 .13 .15 .16	\$3.50 .02 .04 .05 .07 .09 .11 .12 .14 .16 .18	.02 .04 .06 .08 .09 .11 .13 .15 .17 .19	.02 .04 .06 .08 .10 .12 .14 .16 .18 .20 .40	.02 .05 .07 .09 .11 .13 .15 .17 .19 .22 .43	.03 .05 .07 .09 .12 .14 .16 .18 .20 .23 .45	.03 .05 .07 .10 .12 .15 .17 .19 .22 .24 .48	.03 .05 .08 .10 .13 .15 .18 .20 .23 .25 .50
Lb. 10 20 30 40 50 60 70 80 90 100 200 300 400	.02 .03 .06 .08 .09 .11 .12 .14 .15 .30 .45	.02 .03 .05 .07 .08 .10 .11 .13 .15 .16 .33 .49	\$3.50 .02 .04 .05 .07 .09 .11 .12 .14 .16 .35 .53 .70 .88	\$8.75 .02 .04 .06 .08 .09 .11 .13 .15 .17 .19 .38 .56 .76	.02 .04 .06 .08 .10 .12 .14 .16 .18 .20 .40 .60	.02 .05 .07 .09 .11 .13 .15 .17 .19 .22 .43 .64	.03 .05 .07 .09 .12 .14 .16 .18 .20 .23 .45 .68	.03 .05 .07 .10 .12 .15 .17 .19 .22 .24 .48 .72 .96	.03 .05 .08 .10 .13 .15 .18 .20 .23 .25 .50
Lb. 10 20 30 40 50 60 70 80 90 100 200 300 400	.02 .03 .05 .06 .08 .09 .11 .12 .14 .15 .30 .45 .60	\$3.25 .02 .03 .05 .07 .08 .10 .11 .13 .15 .16 .83 .49 .65 .81	\$3.50 .02 .04 .05 .07 .09 .11 .12 .14 .16 .35 .53 .70 .88	\$3.75 .02 .04 .06 .08 .09 .11 .13 .15 .17 .19 .38 .56 .76 .94	.02 .04 .06 .08 .10 .12 .14 .16 .18 .20 .40 .60	.02 .05 .07 .09 .11 .13 .15 .17 .19 .22 .43 .64 .85 1.07	.03 .05 .07 .09 .12 .14 .16 .18 .20 .23 .45 .68 .90 1.13	.03 .05 .07 .10 .12 .15 .17 .19 .22 .24 .48 .72 .95 1.19	.03 .05 .08 .10 .13 .15 .18 .20 .25 .50 .75 1.00
Lb. 10 20 30 40 50 60 70 80 90 100 200 300	.02 .03 .06 .08 .09 .11 .12 .14 .15 .30 .45 .60 .75	\$3.25 .02 .03 .05 .07 .08 .10 .11 .13 .15 .16 .33 .49 .65 .81 .98	\$3.50 .02 .04 .05 .07 .09 .11 .12 .14 .16 .35 .53 .70 .88 1.05	\$3.75 .02 .04 .06 .08 .09 .11 .13 .15 .17 .19 .38 .56 .75 .94 1.18	\$4.00 .02 .04 .06 .08 .10 .12 .14 .16 .18 .20 .40 .60 .80 1.00 1.20 .80	.02 .05 .07 .09 .11 .13 .15 .17 .19 .22 .43 .85 1.07 1.28	.03 .05 .07 .09 .12 .14 .16 .18 .20 .23 .45 .68 .90 1.135 1.35	.03 .05 .07 .10 .12 .15 .17 .19 .22 .24 .48 .72 .95 1.19 1.43 1.67	.03 .05 .08 .10 .13 .15 .18 .20 .28 .25 .50 .75 1.00 1.25 1.50
Lb. 10 20 30 40 50 60 70 800 600 700 800	.02 .03 .06 .06 .08 .09 .11 .12 .14 .15 .30 .45 .60 .75 .90	\$3.25 .02 .03 .05 .07 .08 .10 .11 .13 .15 .16 .33 .49 .65 .81 .98 1.14	\$3.50 .02 .04 .05 .07 .09 .11 .12 .14 .16 .35 .53 .70 .88 1.05 1.24	\$3.75 .02 .04 .06 .08 .09 .11 .13 .15 .17 .19 .38 .56 .76 .94 1.18 1.31	\$4.00 .02 .04 .06 .10 .12 .14 .16 .18 .20 .40 .60 1.00 1.20 1.40	\$4.25 .02 .05 .07 .09 .11 .13 .15 .17 .19 .22 .43 .64 .85 1.07 1.28 1.49	.03 .05 .07 .09 .12 .14 .16 .18 .20 .23 .45 .68 .90 1.13 1.35 1.58	.03 .05 .07 .10 .12 .15 .17 .19 .22 .24 .48 .72 .95 1.19 1.43 1.67	.03 .05 .08 .10 .13 .15 .18 .20 .23 .25 .50 .75 1.00 1.25 1.50 2.20
Lb. 10 20 30 40 50 100 200 100 200 400 500 600 600 600 600 900 900	.02 .03 .06 .06 .08 .09 .11 .12 .14 .15 .30 .45 .60 .75 .90 1.05 1.25	.02 .03 .05 .07 .08 .10 .11 .13 .16 .33 .49 .65 .81 .98 1.14	\$3.50 .02 .04 .05 .07 .09 .11 .12 .14 .16 .35 .53 .70 .88 1.05 1.24	\$3.75 .02 .04 .06 .08 .09 .11 .13 .15 .17 .19 .38 .56 .75 .94 .13 1.31 1.50	\$4.00 .02 .04 .06 .08 .10 .12 .14 .16 .80 1.00 1.20 1.40 1.40 1.80	\$4.25 .02 .05 .07 .09 .11 .13 .15 .17 .19 .22 .43 .64 .85 1.07 1.28 1.49 1.70	.03 .05 .07 .09 .12 .14 .16 .20 .23 .45 .68 .90 1.13 1.35 1.58	.03 .05 .07 .10 .12 .15 .17 .19 .22 .24 .48 .72 .95 1.19 1.43 1.67 1.90 2.14	.03 .06 .08 .10 .13 .15 .18 .20 .23 .25 .50 .75 1.00 1.25 1.50 1.75 2.25
Lb. 10 20 30 40 50 60 70 80 60 700 800 900 1,000 1,000	.02 .03 .05 .06 .08 .09 .11 .12 .14 .15 .30 .45 .60 .75 .1.25 .1.25 .1.35	.02 .03 .05 .07 .08 .10 .11 .13 .16 .33 .49 .65 .81 .98 1.14	\$3.50 .02 .04 .05 .07 .09 .11 .12 .14 .16 .18 .53 .70 .88 1.05 1.23 1.40 1.56	\$3.75 .02 .04 .06 .08 .09 .11 .13 .15 .17 .19 .38 .56 .75 .94 .13 1.31 1.50	\$4.00 .02 .04 .06 .08 .10 .12 .14 .16 .18 .20 .40 .60 1.00 1.20 1.40 1.60	\$4.25 .02 .05 .07 .09 .11 .13 .15 .17 .19 .22 .43 .64 .85 1.07 1.28 1.49 1.70 2.218	.03 .05 .07 .09 .12 .14 .16 .20 .23 .45 .68 .90 1.13 1.35 1.80 2.03 2.25	.03 .05 .07 .10 .12 .15 .17 .19 .22 .24 .48 .72 .95 1.19 1.43 1.67 1.90 2.14	.03 .06 .08 .10 .13 .15 .18 .20 .28 .25 .75 1.00 1.25 1.50 1.75 2.00 2.25 2.25
Lb. 10 20 30 40 50 60 70 80 90 100 500 600 700 800 900 1,000 1,100 1,100 1,100	.02 .03 .05 .06 .08 .09 .11 .12 .14 .15 .30 .45 .60 1.05 1.20 1.35 1.50	\$3.25 .02 .03 .05 .07 .08 .10 .11 .13 .15 .16 .33 .49 .65 .81 .98 1.146 1.46 1.69	\$3.50 .02 .04 .05 .07 .09 .11 .12 .14 .16 .18 .53 .70 .88 1.05 1.23 1.40 1.56	\$3.75 .02 .04 .06 .08 .09 .11 .13 .15 .17 .19 .38 .56 .76 .74 1.13 1.50 1.69 1.69 1.89 1.69 1.69 1.69 1.69	\$4.00 .02 .04 .06 .08 .10 .12 .14 .16 .18 .20 .40 .80 1.00 1.20 1.40 .80 1.20 1.40 .80 2.20	\$4.25 .02 .06 .07 .09 .11 .13 .15 .17 .19 .22 .43 .86 1.49 1.70 1.92 2.18 2.34	.03 .05 .07 .09 .12 .14 .18 .20 .23 .45 .68 .90 .113 1.35 1.35 1.35 2.03 2.23 2.248	.03 .05 .07 .10 .12 .15 .17 .19 .22 .24 .48 .72 .95 1.19 1.43 1.67 2.14 2.38	.03 .05 .08 .10 .13 .15 .18 .20 .25 .50 .75 1.00 1.25 1.50 2.25 2.25 2.25 2.25 2.25
Lb. 10 20 30 40 50 60 70 80 400 500 600 700 800 900 1,00	.02 .03 .05 .06 .08 .09 .11 .12 .14 .15 .80 .75 .90 .1.05 1.35 1.50 1.60	\$3.25 .02 .03 .05 .07 .08 .10 .11 .13 .15 .16 .81 .98 .81 .14 1.30 1.46 1.46 1.78 1.95	\$3.50 .02 .04 .05 .07 .09 .11 .12 .14 .16 .18 .35 .53 .70 .88 1.05 .123 1.42 1.43 1.45 .85 .105 .87 .88 1.05 .88 1.05 .88 1.05 .88 1.05 .88 1.05 .88 1.05 1.05 .88 1.05 .88 1.05 .88 1.05 .88 1.05 .88 1.05 .88 1.05 .88 1.05 .88 1.05 .88 1.05 .88 1.05 .88 1.05 .88 1.05 .88 1.05 .88 1.05 .88 1.05 .88 1.05 .88 1.05 1.	\$3.75 .02 .04 .06 .08 .09 .11 .13 .15 .17 .19 .38 .56 .94 1.13 1.50 1.69 1.88 2.06	\$4.00 .02 .04 .06 .08 .10 .12 .14 .16 .18 .20 .40 .80 1.20 1.40 1.80 2.20 2.20 2.240	\$4.25 .02 .05 .07 .09 .11 .13 .15 .17 .19 .22 .43 .64 .85 1.07 1.28 1.49 1.70 2.213 2.34 2.35	.03 .05 .07 .09 .12 .14 .16 .18 .22 .23 .45 .90 1.13 1.85 1.80 2.25 2.25 2.27 2.27	.03 .06 .07 .10 .12 .15 .17 .19 .22 .48 .72 .96 1.19 1.43 1.43 1.43 1.43 2.62 2.88 2.88	.03 .05 .08 .10 .13 .15 .18 .20 .23 .25 .50 .75 1.00 1.25 2.25 2.25 2.25 2.25 2.25 2.25 2.25
Lb. 100 200 300 400 500 400 500 400 500 700 800 900 1,000 1,100 1,200 1,300 1,300 1,300	.02 .03 .06 .08 .09 .11 .12 .14 .15 .30 .45 .60 .75 .90 .1.20 1.35 1.50 1.65 1.80	\$3.25 02 .03 .05 .07 .08 .10 .11 .13 .15 .16 .33 .49 .65 .81 .146 1.30 1.46 1.46 1.46 1.79 1.91	\$3.50 .02 .04 .05 .07 .09 .11 .12 .14 .16 .35 .53 .70 .88 .1.05 .1.23 .1.40 .1.58 .1.78 .1.98 .1.78 .2.10	\$3.75 .02 .04 .06 .08 .09 .11 .13 .15 .17 .19 .38 .56 .94 .91 .13 1.51 1.51 1.69 1.69 1.89 2.06 2.24	\$4.00 .02 .04 .06 .08 .10 .12 .14 .16 .18 .20 .40 .80 1.20 1.40 .80 1.20 1.40 .80 1.20 2.00 2	\$4.25 .02 .06 .07 .09 .11 .13 .15 .17 .19 .22 .43 .64 .85 .1.07 .1.28 .1.49 .1.92 .2.14 .2.54 .2.57	.03 .05 .07 .09 .12 .14 .16 .20 .23 .45 .88 .90 1.13 1.85 1.58 2.03 2.24 2.24 2.25 2.24 2.29 2.29	.03 .05 .07 .10 .12 .15 .17 .19 .22 .48 .72 .95 1.19 1.43 1.67 1.90 2.14 2.38 2.62 2.85 3.09	.03 .05 .08 .10 .13 .15 .18 .20 .23 .25 .50 .75 1.00 1.25 1.75 2.00 2.25 2.75 3.00 2.75
Lb. 10 20 30 40 50 60 70 80 90 100 500 600 700 800 900 1,100 1,200 1,300 1,400 1,400 1,400 1,400	.02 .03 .06 .08 .09 .11 .12 .14 .15 .30 .75 .90 .1.35 1.20 1.35 1.50 1.65 1.80 1.96 2.10	\$3.25 .02 .03 .05 .07 .08 .10 .11 .13 .15 .16 .83 .49 .65 .81 .14 1.30 1.46 1.63 1.79 1.95 1.95 2.21 2.28	\$3.50 .02 .04 .05 .07 .09 .11 .12 .14 .16 .18 .35 .53 .70 .88 .87 .70 .88 1.40 1.23 1.40 1.58 1.75 2.10 2.24 2.24 2.24 2.24 2.24 2.24	\$3.75 .02 .04 .06 .08 .09 .11 .15 .17 .19 .38 .56 .76 .94 1.13 1.50 1.169 1.80 2.25 2.46	\$4.00 .02 .04 .06 .08 .10 .12 .14 .16 .18 .20 .80 1.00 1.20 1.40 1.80 2.00 2.20 2.40 2.80	\$4.25 .02 .05 .07 .09 .11 .13 .15 .17 .19 .22 .43 .64 .85 1.07 1.28 1.49 1.70 2.13 2.34 2.55 2.77 2.98	.03 .05 .07 .09 .12 .14 .16 .18 .23 .45 .90 1.135 1.58 2.23 2.24 2.23 2.24 2.24 2.27 2.28 2.27 3.15	.03 .06 .07 .10 .12 .15 .17 .19 .22 .24 .48 .72 .96 1.19 1.67 1.90 2.14 2.38 2.38 2.38 3.09 3.39 3.39 3.39 3.39 3.39 3.39 3.39	.03 .06 .08 .10 .13 .15 .18 .20 .23 .25 .75 1.00 1.25 1.50 2.25 2.25 2.25 2.25 2.25 2.25 3.25 3.25
Lb. 100 200 300 400 500 600 700 800 900 1,000 1,200 1,	.02 .03 .06 .08 .09 .11 .12 .14 .15 .30 .75 .90 .1.35 .1.50 .1.85 .1.56 .1.80 .1.96 .2.10 .2.240	\$3.25 .02 .03 .05 .07 .08 .10 .11 .13 .15 .16 .83 .49 .65 .81 .98 1.14 1.39 1.46 1.69 1.46 1.69 2.21 2.28 2.46 2.46	\$3.50 .02 .04 .05 .07 .09 .11 .12 .14 .16 .18 .35 .70 .88 1.23 1.40 1.58 1.79 2.10 2.24 2.60 2.60	\$3.75 .02 .04 .06 .08 .09 .11 .13 .15 .17 .19 .38 .56 .75 .94 1.13 1.59 1.80 2.25 2.45 2.46 2.83 2.83	\$4.00 .02 .04 .06 .08 .10 .12 .14 .16 .18 .20 .40 .80 1.00 1.20 1.40 1.20 2.00 2.00	\$4.25 .02 .06 .07 .09 .11 .13 .15 .17 .19 .22 .43 .64 .85 .1.07 .1.28 .1.49 .1.92 .2.14 .2.54 .2.57	.03 .05 .07 .09 .12 .14 .16 .18 .20 .23 .45 .68 .90 .113 1.35 1.55 2.23 2.48 2.23 2.48 2.29 3.45 2.29 3.45 3.45 3.45 3.45 3.45 3.45 3.45 3.45	.03 .06 .07 .10 .12 .15 .17 .19 .22 .24 .48 .72 .96 1.43 1.67 1.90 2.148 2.62 2.85 3.09 8.85 8.57	.03 .06 .08 .10 .13 .15 .18 .20 .28 .25 .75 1.00 1.75 2.20 2.25 2.25 2.25 2.25 2.25 2.25 2.2
Lb. 100 200 300 400 500 600 700 2000 3000 4000 5000 6000 7000 1,0000 1,2000 1,2000 1,4000 1,5000 1,5000 1,6000 1,7	.02 .03 .06 .08 .09 .11 .12 .14 .15 .80 .45 .90 .1.25 1.25 1.80 1.96 2.10 2.25 2.40	\$3.25 -02 .03 .05 .07 .08 .10 .11 .13 .15 .16 .33 .49 .65 .81 .44 .81 .98 1.146 1.30 1.463 1.79 1.95 2.244 2.60 2.76	\$3.50 .02 .04 .05 .07 .09 .11 .14 .16 .18 .35 .70 .88 1.05 1.23 1.40 1.56 1.23 2.28 2.28 2.28 2.28 2.98	\$3.75 .02 .04 .06 .08 .09 .11 .13 .15 .17 .19 .38 .56 .76 .74 1.18 1.31 1.50 1.69 1.18 2.06 2.24 2.28 2.81 3.09 3	\$4.00 .02 .04 .06 .08 .10 .12 .14 .16 .18 .20 .40 .80 1.20 1.40 1.20 1.40 2.20 2.20 2.20 2.30 3.00 3.00	\$4.25 .02 .05 .07 .09 .11 .13 .15 .17 .19 .22 .43 .64 .85 1.28 1.49 1.70 1.91 2.13 2.34 2.34 2.34 3.34	.03 .05 .07 .09 .12 .14 .16 .18 .20 .23 .45 .68 .90 .113 .1.35 .1.35 .2.25 .2.26 .2.27 .2.28 .20 .20 .20 .20 .20 .20 .20 .20 .20 .20	.03 .05 .07 .10 .12 .15 .17 .19 .22 .24 .48 .72 .95 .119 1.43 1.43 1.49 2.62 2.62 3.83 3.09 8.85 8.85 8.04	.03 .05 .08 .10 .13 .15 .18 .20 .23 .50 .75 .1.00 1.25 2.50 2.75 2.50 2.75 2.50 2.75 2.50 2.75 2.50 2.75 2.75 2.75 2.75 2.75 2.75 2.75 2.75
Lb. 10 20 30 40 50 60 70 80 900 1,100 1,200 1,300 1,100 1,200 1,50	.02 .03 .06 .08 .09 .11 .12 .14 .15 .30 .75 .90 .1.35 .1.50 .1.85 .1.56 .1.80 .1.96 .2.10 .2.240	\$3.25 .02 .03 .05 .07 .08 .10 .11 .13 .15 .16 .83 .49 .65 .81 .98 1.14 1.39 1.46 1.69 1.46 1.69 2.21 2.28 2.46 2.46	\$3.50 .02 .04 .05 .07 .09 .11 .12 .14 .16 .18 .35 .70 .88 1.23 1.40 1.58 1.79 2.10 2.24 2.60 2.60	\$3.75 .02 .04 .06 .08 .09 .11 .13 .15 .17 .19 .38 .56 .75 .94 1.13 1.59 1.80 2.25 2.45 2.46 2.83 2.83	\$4.00 .02 .04 .06 .08 .10 .12 .14 .16 .80 .80 1.00 1.40 1.40 1.80 2.20 2.40 2.20 2.40 2.80 3.0	\$4.25 .02 .05 .07 .09 .11 .13 .15 .17 .19 .22 .43 .64 .85 1.07 1.28 1.49 1.70 2.13 2.23 2.23 2.25 2.27 2.98 3.40	.03 .05 .07 .09 .12 .16 .16 .20 .23 .45 .69 .90 1.13 1.85 1.80 2.24 2.24 2.27 2.24 8.86 8.86	.03 .05 .07 .10 .12 .15 .17 .19 .22 .24 .48 .72 .95 1.19 1.43 1.43 1.43 2.38 2.38 2.38 3.89 3.85 3.85 3.85 3.85 3.85	.03 .06 .08 .10 .13 .15 .18 .20 .28 .25 .75 1.00 1.75 2.20 2.25 2.25 2.25 2.25 2.25 2.25 2.2

TABLE OF NATURAL SINES, COSINES. TANGENTS. AND COTANGENTS.

EXPLANATION.

Given an angle, to find its sine, cosine, tangent, and cotangent: EXAMPLE.—Find the sine, cosine, tangent, and cotangent of 37° 24′.

Look in the table of natural sines along the tops of the pages, and find 37°. Glancing down the left-hand column marked (′), until 24 is found, find opposite this 24 in the column marked sine and headed 37°, the number .60738; then .60738 = sin 37° 24′. Similarly, find in the column marked cosine and headed 37°, the number .79441, which corresponds to cos 37° 24′. So. also, find in the column marked tangent and headed 37°, and opposite 24' the number .76456; and in the column marked cotangent and headed 37°, and opposite 24', the number 1.30795.

In most of the tables published, the angles run only from 0° to 45° at the heads of the columns; to find an angle greater than 45°, look at the bottom of the page and glance upwards, using the extreme right-hand column to find minutes, which begin with 0 at the bottom and run upwards, 1, 2, 3, etc.,

up to 60.

EXAMPLE.—Find the sine of 77° 43'.

Look along the bottom of the tables until the column marked sine and marked 77° is found. Glancing up the column of minutes on the right until 43' is found, find opposite 43' in the column marked sine at the bottom and marked 77°, the number .97711; this is the sine of 77° 43'. Similarly, the cosine, tangent, and cotangent may be found.

To find the sine, cosine, tangent, or cotangent of an angle whose exact value is not given in the table:

Rule.—Find in the table the sine, cosine, tangent, or cotangent corresponding

to the degrees and minutes of the angle.

For the seconds, find the difference of the values of the sine, cosine, tangent, or cotangent taken from the table between which the seconds of the angle fall: multiply this difference by a fraction whose numerator is the number of seconds in the given angle and whose denominator is 60.

If sine or tangent, add this correction to the value first found; if cosine or

cotangent, subtract the correction.

EXAMPLE.—Find the sine, cosine, tangent, and cotangent of 56° 43' 17".
Sin 56° 43' = .83597. Sin 56° 44' = .83613. Since 56° 43' 17" is greater than 56° 43' and less than 56° 44', the value of the sine of the angle lies between .83597 and .83613; the difference equals .83613 - .83597 = .00016; multiplying this by the fraction $\frac{1}{46}$, .00016 $\times \frac{1}{66}$ = .00005, nearly, which is to be added to .83597, the value first found, or .83597 + .00005 = .83602. Hence, sin 56° 43′ 17″ = .83602.

 $\cos 56^{\circ} 43' = .54878$; $\cos 56^{\circ} 44' = .54854$; the difference equals .54878 - .54854 = .00024, and .00024 \times 15 = .00007, nearly. Now, since the cosine is desired, we must subtract this correction from cos 560 42', or .54878; subtracting, .54878 - .00007 = .54871. Hence, $\cos 56^{\circ} 43' 17'' = .54871$.

Given the sine, coaine, tangent, or cotangent, to find the engle corresponding:

EXAMPLE.—The sine of an angle is .47486; what is the angle?

Consulting the table of natural sines, glance down the columns marked sine until .47486 is found, opposite 21' in the left-hand column and under the column headed 28°. Therefore, the angle whose sine = .47486 is 28° 21', or $\sin 28^{\circ} 21' = .47486.$

To find the angle corresponding to a given sine, cosine, tangent, or

cotangent whose exact value is not contained in the table:
Rule.—Find the difference of the two numbers in the table between which the
given sine, cosine, tangent, or cotangent falls, and use the number of parts in this
difference as the denominator of a fraction.

Find the difference between the number belonging to the smaller angle and th given sine, cosine, tangent, or colangent, and use the number of parts in the dif-ference just found as the numerator of the fraction mentioned above. Multiple this fraction by 60, and the result will be the number of seconds to be added to the smaller angle.

EXAMPLE.—Find the angle whose sine equals .57698.

Looking in the table of natural sines, in the column marked sine, it is found between .57691 = $\sin 35^{\circ}$ 14' and .57715 = 35° 15'. The difference between them is .57715 - .57691 = .00024, or 24 parts. The difference between the sine of the smaller angle, or $\sin 35^{\circ}$ 14' = .57691, and the given sine, or .57698, is .57698 - .57691 = .00007, or 7 parts.

Then, $\frac{7}{44} \times 60 = 17.5''$, and the angle = 35° 14' 17.5", or $\sin 35^{\circ}$ 14' 17.5"

The cosecant of an angle is equal to the reciprocal of its sine, and the secant is equal to the reciprocal of its cosine. Hence, to multiply a quantity by the cosecant, divide it by the sine; or, to divide it by the cosecant, multiply it by the sine. Similarly, to multiply a quantity by the secant, angle, divide it by the cosine; or, to divide it by the secant, multiply it by the cosine.

	0	0	1	0	2	ю	3	0	4	0	
	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	_
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 11	.00000 .00029 .00058 .00087 .00116 .00145 .00175 .00204 .00282 .00291 .00349 .00349 .00407 .00406 .00465	1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 99999 99999 99999 99999 99999	.01745 .01774 .01803 .01803 .01862 .01891 .01990 .01978 .02007 .02005 .02006 .02065 .02152 .02181 .022181	.99985 .99984 .99983 .99982 .99882 .99882 .99980 .99980 .99979 .99979 .99979 .99978 .99977 .99976 .99976	.03490 .03519 .03548 .03577 .03606 .03635 .03664 .03693 .03723 .03781 .03781 .03839 .03936 .03936 .03936 .03936 .03936		.05284 .05283 .05292 .05321 .05350 .05379 .05408 .05437 .05468 .05624 .05624 .05682 .05682 .05682 .05689 .05689	.99863 .99861 .99860 .99855 .99855 .99854 .99851 .99841 .99844 .99844 .99844 .99844 .99843 .99839	.06976 .07005 .07005 .07034 .07063 .07092 .07121 .07150 .07179 .07287 .07287 .07286 .07295 .07324 .07352 .07382 .07411 .07440	.99756 .99764 .99752 .99760 .99748 .99744 .99744 .99744 .99738 .99736 .99736 .99739 .99727 .99723 .99723 .99723 .99723 .99723	60 59 58 57 56 55 54 58 52 51 50 49 48 47 46 45 44
18 19 20 21 22 23 24 25 26 27 28 29	.00524 .00553 .00582 .00611 .00640 .00669 .00698 .00727 .00756 .00785 .00814	.99999 .99998 .99998 .99998 .99998 .99997 .99997 .99997 .99997	.02269 .02298 .02327 .02356 .02385 .02414 .02443 .02472 .02501 .02530 .02560 .02589	.99974 .99974 .99973 .99972 .99972 .99971 .99970 .99969 .99969 .99968 .99967	.04013 04042 .04071 .04100 .04129 .04159 .04188 .04217 .04246 .04275 .04304 .04333	.99919 .99918 .99917 .99916 .99915 .99913 .99912 .99911 .99910 .99909 .99907 .99906	.05756 .05785 .05814 .05844 .05873 .05902 .05931 .05960 .05989 .06018 .06047	.99834 .99833 .99831 .99829 .99827 .99826 .99824 .99822 .99821 .99819 .99817 .99815	.07498 .07527 .07556 .07585 .07614 .07643 .07672 .07701 .07730 .07759 .07759	.99719 .99716 .99714 .99712 .99710 .99708 .99705 .99701 .99699 .99696 .99694	42 41 40 39 38 37 36 35 34 33 32 31
30 31 32 33 34 35 36 37 38 39 40	.00673 .00902 .00931 .00960 .00989 .01018 .01047 .01105 .01134	.99996 .99996 .99995 .99995 .99995 .99994 .99994 .99994	.02618 .02647 .02676 .02706 .02734 .02763 .02792 .02821 .02850 .02879 .02908	.99965 .99964 .99963 .99963 .99962 .99961 .99960 .99959 .99959	.04362 .04391 .04420 .04449 .04478 .04507 .04536 .04565 .04564 .04623	.99905 .99904 .99902 .99901 .99898 .99897 .99896 .99894 .99893 .99893	.06105 .06184 .06163 .06192 .06221 .06250 .06279 .06308 .06337 .06366 .06395	.99813 .99812 .99810 .99808 .99806 .99804 .99803 .99801 .99797 .99797	.07846 .07875 .07904 .07933 .07962 .07991 .08020 .08049 .08078 .08107	.99689 .99687 .99685 .99683 .99680 .99678 .99676 .99673 .99671	29 28 27 26 25 24 23 22 21 20
41 42 48 44 45 46 47 48 49 50	.01103 .01222 .01251 .01280 .01309 .01388 .01367 .01396 .01425	.99993 .99993 .99992 .99992 .99991 .99991 .99990 .99990	.02938 .02967 .02996 .03025 .03054 .03083 .03112 .03141 .03170	.99957 .99956 .99955 .99954 .99953 .99952 .99952 .99951 .99950 .99949	.04682 .04711 .04740 .04769 .04798 .04827 .04856 .04885 .04914 .04943	.99890 .99889 .99888 .99886 .99885 .99882 .99881 .99879	.06424 .06453 .06482 .06511 .06540 .06569 .06598 .06627 .06656 .06685	.99793 .99792 .99790 .99788 .99786 .99784 .99782 .99780 .99778	.08165 .08194 .08223 .08252 .08261 .08310 .08339 .08368 .08397 .08426	.99666 .99664 .99661 .99659 .99657 .99654 .99652 .99649 .99647	19 18 17 16 15 14 13 12 11
51 52 53 54 55 56 57 58 59 60	.01483 .01513 .01542 .01571 .01600 .01629 .01658 .01687 .01716 .01745	.99889 .99989 .99988 .99988 .99987 .99986 .99986 .99985	.03228 .03257 .03286 .03316 .03345 .03374 .03403 .03432 .03461 .03490	.99948 .99947 .99946 .99945 .99944 .99943 .99941 .99940 .99939	.04972 .05001 .05080 .05059 .05088 .05117 .05146 .05175 .05205 .05234	.99876 .99873 .99872 .99870 .99869 .99866 .99864 .99863	.06714 .06743 .06773 .06802 .06831 .06860 .06889 .06918 .06947 .06976	.99774 .99772 .99770 .99768 .99766 .99764 .99762 .99758 .99756	.08455 .08484 .08513 .08542 .08571 .08600 .08629 .08658 .08687 .08716	.99642 .99639 .99637 .99635 .99632 .99630 .99627 .99625 .99622 .99619	9 8 7 6 5 4 3 2 1
ľ		90	88			70	86		85		,

	5	ρ	6	0	7	0	8	•	9	ю	Ţ,
1	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sige	Cosine	1
0	.08716	.99619	.10458	.99452	.12187	.99255 .99251	.13917 .13946	,99027 ,99028	.15643 .15672	.98760	60 50
1 2	.08745 .08774	.99617 .99614	.10482	.99446	.12245	.90248	.13975	.99019	.15701	98746	58
3	.08808	99612	,10540	.99443	.12274	.99244	.14004	.99015	.15730	.96755	57
4	.06881	.99612 .99609	.10569	.99440	.12302	.99240	.14088	,99011	.15758	.98751	56
5	.08860	.99607	.10597	.99437	.12331	.99287	.14061	.99006	.15787	.98746	55 54
6	.08889	.99604	.10626	.99434	.12860	.99233	.14090	.99002 .96998	.15816 .15845	.98787	53
7	.08918	,99602 ,99599	.10655 .10684	.99431 .99428	.12889 .12418	.99226	.14119 .14148	.98994	.15878	.96732	52
8	.08947	.99596	.10718	.99424	.12447	.99222	.14177	,98990	.15902	,98728	51
10	.09005	.99594	.10742	,99421	.12476	.99219	.14205	.98986	.15931	.98728	59
11 12	.09034 .09063	.99591 .99588	.10771	.99418 .99415	.12504 .12533	.99215 .99211	.14284 .14268	.98982 .98978	.15959 .15988	.98718 .98714	49 48
13	.09092	.99586	.10829	.99412	.12562	.99206	.14292	.98978	.16017	.98709	47
14	.09121	.99588	.10858	.99409	.12591	.99204	.14320	.98869	.16046	.98704	46
15	.09150	,99580	.10887	.99406	.12620	.99200	.14849	.98965 .98961	.16074	.98799 .98695	45 44
16	.09179	.99578	.10916	.99402 .99399	.12649 .12678	.99197 .99193	.14378	.98957	.16103	.98690	43
17	.09208	.99575 .99572	.10945 .10973	.99396	.12678	.99189	.14436	.98953	.16160	.98686	42
19	.09257	.99570	.11002	.99393	.12785	.99186	.14464	.98948	.16189	.98681	41
20	.09295	.99567	.11081	.99890	.12764	.99182	.14498	.98944	.16218	.98676	10
21	.09324	.99564	.11060	.99386	.12798	.99178	.14522	.98940	.16246	.98671	39
22	.09358	.99562	.11089	.99383	.12822	.99175	.14551	.98936	.16275 .16304	.98667 .98662	38
23	.09582	.99559	.11118	.99380 .99377	.12851 .12880	.99171 .99167	.14580 .14608	,98981 ,98927	.16333	.98657	36
24 25	.09411 .09440	.99556 .99553	.11147 .11176	.99374	.12880	.99163	.14637	.98923	16861	99652	35
26	.09469	.99551	.11205	.99370	.12937	.99160	.14666	.98919	.16390	.98648	34
27	.09498	.99548	.11284	.99367	.12966	.99156	.14695	.98914	.16419	.98643	33
28	.00527	.99545	.11263	,99364	.12995	.99152	.14723	.98910 .98906	.16447	.98638 .98633	32 31
29 30	.09556 .09585	.99542 .99540	.11291 .11820	.99860 .99357	.13024 .13053	.99148 .99144	.14752 .14781	.98902	.16476 .16505	.96629	30
				*****	.13081	.99141	.14810	.98897	.16533	.98624	29
31 32	.09614	.99537 .99534	.11349 .11378	.99854 .99351	.13110	.99137	.14838	.96898	.16562	.98619	28
33	.09671	.99531	.11407	.99347	.13139	.99133	.14867	.98889	.16591	.98614	27
34	.09700	.99528	.11436	.99344	.13168	.99129	.14896	.98884	.16620	.98609	26
35	.09729	.99526	.11465	.99341	.13197	.99125	.14925	,98880	.16648 .16677	.98604 .98600	25 24
36	.09758	.99523	.11494	.99837 .99334	.13226 .13254	.99122 .99118	.14954 .14982	.98876 .98671	.16706	.98595	23
37	.09787	.99520 .99517	.11523 .11552	.99331	.13283	.99114	.15011	.98867	.16734	.98590	22
39	.09845	.99514	.11580	.99327	.13312	.99110	.15040	.98863	.16763	.98585	21
40	.09874	.99511	.11609	.99324	.13341	.99106	.15089	.98858	.16792	.98580	20
41 42	.09903	.99508 .99506	.11638 .11667	.99820 .99317	.18370 .18399	.99102 .99098	.15097 .15126	.96854 .98849	.16820 .16849	.99575 .98570	19 18
43	.09961	.99503	.11696	.99314	.18427	.99094	.15156	.98845	16878	.98565	17
44	.09990	.99500	.11725	.99310	.13456 .18485	.99091	.15184	.98841	.16906	.96561	16
45	.10019	.99497	.11754	.99307	.18485	.99067	.15212	.98836	.16935	.96556 .96551	15
46	.10048	.99494 .99491	.11783	.99303 .99300	.18514 .18543	.99068 .99079	.15241 .15270	.98832 .98827	.16964 .16992	.98546	14
47 48	.10077	.99491 .99488	.11812	.99297	.13572	.99075	.15299	.96823	.17021	.98541	12
49	.10185	.99485	.11889	.99293	.13800	.99071	.15327	.96818	.17050	.98536	11
50	.10164	.99482	.11898	.99290	.13629	.99067	.15356	.96814	.17078	.98531	10
51	10192	.99479	.11927	.99286	.13658	.99063	.15886	.98869	.17107	.98526	9
52	.10221	.99476	.11956	.99283	.18687	.99059	.15414	.98805	.17186	.98521 .98516	8
53	.10250	.99473	.11985	.99279	.13716 .13744	.99055 .99051	.15442	.98800 .98796	.17164 .17198	.98616 .98511	3
54	.10279 .10368	.99470 .99467	.12014 .12043	.99276 .99272	.18744	.99047	.15500	.98791	.17222	.98506	81
55 56	.10368	.99464	.12043	.99269	.13802	.99043	.15529	.96787	.17250	.98601	4
57	.10366	.99461	.12160	.99265	.13831	.99039	.15557	.98782	17279	.96496	3
58	.10395	.99458	.12129	.99262	,13860	.99085	.15586	.98778	.17308	.98491	3
59 60	.10424 .10458	.99455 .99452	.12158 .12187	.99258 .99255	.18889 .18917	.99031 .99027	.15615 .15643	.96773 .96769	.17886 .17865	.98486 .98481	0
-	Cosine	Sine	Cosine	Sine	Coeine	Sine	Cosine	Sine	Costne	Sine	1
,		1		<u> </u>	<u> </u>			<u> </u>	<u> </u>	-	1
	8	40	8	30	85	20	8:	lo	80	٥	

.1	line	Cosine									1
.1		Comine	Sine	Conine	Sine	Cosine	Sine	Cosine	Sine	Cooine	
1:1	7365 7363	.98481	.19061	.98163	.20791	.97815	.22405	.97437	.34192	.97080	6
	7422	.98476 .98471	.19109	.98157	.20820	.97809	.22586 .22562	.97430	.34330	.97028 .97015	5
	7451	.98466	.19138 .19167	.96152 .96146	.20848 .20877	.97808 .97797	.22580	.97424 .97417	.24249	.97008	5
1.3	7479	.98461	.19195	.98140	.20905	.97791	.22608	.97411	.24305	.97001	5
.1	7508	.98465	.19234	.98135	,20983	.97784	.22687	.97404	.24888	.96994	5
-	175 37 175 6 5	.98450	.19252	.98129	,20962	.97778	.22665	.97398	.24882 .34890	.96987 .96980	5
13	17504	.98445 .98440	.19281 .19309	.96124 .96118	.20990 .21019	.97772 .97766	.22698 .22722	.97391 .97384	.34418	.96960	5
1:	17623	.98435	.19888	.98112	.21047	.97760	.22750	.97378	.34446	.96966	5
13	17651	.98430	.19366	.98107	.21076	.97754	.22778	.97371	.24474	.96959	5
	17680	.98425	.19895	.90101	.21104	.97748	.22807	.97865	.24508 .24531	.96952 .96945	1
	.17708 \ .17737	.98420 .98414	.19423	.98096 .98090	.21132 .21161	.97742	.22885 .22863	.97858 .97851	.24559	.96937	1
	17766	.98409	.19481	98084	.21189	.97729	.22892	.97845	.24587	.96930	4
١.	17794	.98404	.19509	,98079	.21218	.97728	.22920	.97338	.24615	.96923	1
8 \ .	17823	.98399	10588	.90073	.21246	.97717	.22948 .22977	.97881 .97825	.24644	.96916 .96909	4
	.17852	.98394	.19566	.98067 .98061	.21275 .21808	.97711 .97705	.22977	.97318	.34700	.96902	4
18	.17880 .17909	.96383	1 .19628	.98056	.21831	.97698	.23088	.97311	.24728	.96894	4
20	.17937	.96378	.19652	.98050	.21780	.97692	.23062	.97304	.24756	.96867	4
n l	,17966	,98373	.19680	.98044	.21386	.97686	.23090	.97298	.24784	.96890 .96873	8
22	.17995	.98868	.19769	.98039 .98033	.21417 .21445	.97680 .97678	.23118 .23146	.97291 .97284	.24818 .24841	.96866	9
23	.18023	.96362 .96357	.19766	.98027	.21474	.97667	.28175	.97278	.24889	.96858	1
24 25	.18007	.96352	19794	.99021	.21502	.97661	.23208	.97271	.24897	:96851	1
*	18109	,98347	.19828	.98016	.21530	.97655	.23231	.97264	.24925	.96844 .96837	3
27	.18138	.98841	.19851 .19880	.98010 .98004	.21559 .21587	.97648 .97642	.23260 .23288	.97257 .97251	.24954 .24982	.96829	1
28	.18166	.98336 .98381	.19908	.97998	.21616	.97636	.28316	.97244	.25010	.96822	1 8
29 30	.18195 .18224		,19937	.97992	.21644	.97630	.28845	.97237	.25088	.96815	3
31	.18252	.98320	.19965	.97987	.21672	.97623	.23878	.97280	.25066	.96807	2
32	18281	.98315	.19994	.97981 .97975	.21701 .21729	.97617 .97611	.23401 ,23429	.97223 .97217	.25094 .25122	.96800 .96793	2 2
33	.18300	98810	.20051	97969	.21758	.97604	.23458	97210	.25151	.96786	1 2
34 35	.18336	98299	.20079	.97963	.21786	.97598	.23486	.97203	.25179	.96778	1
36	.1839	98294	.20108	.97968	.21814	.97592 .97585	.28514 .23542	.97196 .97189	.25207 .25285	.96771 .96764	1
37	.18424	98288	.20136 .20165	.97952 .97946	.21843 .21871	.97579	.23542	.97182	.25268	.96756	1 2
38	1845		.20193	.97940	.21899	.97573	.23599	.97176	.25291	96749	1
20	.1850		.20222	.97984	.21928	.97566	.23627	.97169	.25820	.96742	2
41	.1853	98287	.20250	.97928	.21956	.97560	.23656 .23684	.97162	.25848 .25876	.96734 .96727	1
42	.1856	98261 98256	.20279	.97922 .97916	.21985 .22013	.97553 .97547	.23684	.97155 .97148	.25404	.96719	ľi
43	.1859	5 .98250 4 .98250	20336	.97910	.22041	.97541	,23740	.97141	.25432	.96712	1
44 45	.1862 .1865	98245	.20364	.97905	.22070	.97534	.23769	.97184	.25460	.96705	1
46	.1868	98240	20393	.97899 .97898	.22098	.97528	.23797 .23825	.97127 .97120	.25488 .25516	.96697 .96699	l
- 47	.1871	0 .98234	.20421	.97898	.22126 .22155	.97521 .97515	.23820	.97120	.25545	.96682	H
48	.1878			.97881	.22183	.97508	,23882	.97106	.25578	.96675	1
19				.97875	.22212	.97502	.23910	.97100	.25601	.96667	
		.98212	.20585	.97869	.22240	.97496	.23988	.97093	.25629	.96660	
51 52	1885	2 .9620	.20563	.97863	.22268	.97489	.23966 .23996	.97066 .97079	.25657 .25685	.96658 .96645	1
58	.1888	1 .9620		.97857 .97851	.22297 .22325	.97488 .97476	.24023	.97079	.25718	.96638	1
54	, 1891		.20649	.97845	.22353	.97470	.24051	.97065	.25741	.96630	1
55		9818	.20677	.97839	.22382	.97463	.24079	.97058	.25769	.96623	
56 57	1899	6 .9817	.20706	.97833 .97837	.22410	.97457 .97450	.24196 .24136	.97051 .97044	.25798 .25826	.96615 .96608	1
i 58	,1902	9817		.97821	.22438 .22467	.97444	.24156	.97037	.25864	.96600	
50				.97815	.23495	.97487	.24192	.97030	.25002	.96598	
F	Cost	_	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	-
١,		_'	- <u>-</u>	<u> </u>	<u> </u>			<u></u>		!	
T.	1	79°	1 7	80	7	~	70	o''	78	~	

0 1 1 2 3 3 4 4 5 6 7 7 8 9 10 11 12 13 14 11 16 11 17 18 19 20 20 20 20 20 20 20 20 20 20 20 20 20	Sine 25982 25910 25938 25964 26022 26050 26079 26135 26165 26161 26219 26219 26247 26239 26351 26359 26361 26443	98583 .98585 .98578 .98578 .98578 .98562 .98547 .98582 .98582 .98582 .98582 .98692 .98692 .98494 .98496 .98	Sine 27564 27562 27620 27646 27704 27759 27759 27759 27843 27843 27843 27871 27899 27977 27983 27983 280011	Cosine .96128 .96118 .96110 .96102 .98094 .98094 .98078 .98054 .98054 .98087 .98087 .98089 .98089 .98089	Sine .39237 .39265 .29295 .29321 .29348 .29404 .29487 .29487 .29615 .29615	Couine .95680 .95622 .95613 .95603 .95586 .95586 .95571 .95662 .95563 .95563 .95586	Sine .30902 .30929 .30945 .30965 .31040 .31068 .81098 .81123 .31151 .31178	Cosine .95106 .95097 .95088 .95079 .95061 .95062 .95043 .95024 .95016	Sine .32557 .32584 .32612 .32639 .32667 .32694 .32772 .32749 .32777 .32804 .32832	Cosine .94552 .94542 .94533 .94523 .94514 .94696 .94496 .94476 .94476 .94477	50 50 56 56 56 56 56 53 51 52 51 50
1 2 3 4 5 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24	25910 25938 25966 25994 26022 26020 26079 26107 26185 26163 26191 26219 26247 26255 26359 26359 26359 26443	.96565 .96578 .96578 .96562 .96562 .96564 .96547 .96544 .96524 .96517 .96509 .96692 .96493 .9	.27592 .27629 .27648 .27676 .27704 .27731 .27759 .27787 .27815 .27843 .27871 .27899 .27992 .27992 .27963 .28011 .28039	.96118 .96110 .96102 .96094 .96096 .96078 .96070 .96062 .96054 .96046 .96029 .96029 .96021 .96018	.29265 .29293 .29328 .29376 .29376 .29404 .29432 .29460 .29487 .29515 .29543 .29571 .29599	.95622 .95613 .95605 .95596 .95596 .95588 .96579 .95571 .95562 .96564 .95645	.30929 .30967 .30985 .31012 .31040 .31068 .31095 .31123 .31151 .31178	.95097 .95088 .95079 .95070 .95061 .95062 .95048 .95083 .95024 .95015	.32584 .32612 .32639 .32667 .32694 .32722 .32749 .32777 .32804 .32832	.94542 .94533 .94523 .94514 .94504 .94495 .94485 .94476 .94466 .94457	58 57 58 58 54 53 53 51 59
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24	25988 25986 25984 26922 26050 26079 26107 26185 26183 26191 26219 26217 26319 26319 263219 263219 263219 263219 263219 26321 2	.96578 .96570 .96562 .96565 .96547 .96542 .96532 .96524 .96617 .96509 .96494 .96496 .96471 .96463 .96463	.27620 .27648 .27676 .27704 .27751 .27759 .27787 .27815 .27843 .27871 .27899 .27927 .27965 .27963 .28011 .29039	.96110 .96102 .96094 .96096 .96078 .96070 .96062 .96054 .96046 .96087 .96029 .96029 .96018	.29293 .29321 .29348 .29376 .29404 .29432 .29460 .29487 .29615 .29648 .29571 .29599	.95613 .95605 .95596 .95588 .95579 .96571 .95663 .95564 .95546	.80967 .80985 .81012 .81040 .81068 .81095 .81128 .81151 .81178	.95088 .95079 .95070 .95061 .95062 .95048 .95083 .95024 .95015	.32612 .32639 .32667 .32694 .82722 .32749 .32777 .32804 .32832	.94533 .94523 .94514 .94504 .94495 .94485 .94476 .94457	58 57 58 58 54 53 53 51 59
3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24	25966 25994 26022 26050 28079 26107 26135 26191 26219 26275 26351 26359 26359 26351 26443	.96570 .96562 .96556 .96547 .96540 .96532 .96524 .96517 .96509 .96502 .96494 .96478 .96463 .96463 .96463	.27648 .27676 .27704 .27731 .27759 .27787 .27815 .27843 .27871 .27899 .27927 .27965 .27983 .28011 .28039	.96102 .96094 .96096 .96078 .96070 .96062 .96054 .96046 .96029 .96029 .96021 .96018	.29321 .29348 .29378 .29404 .29432 .29460 .29487 .29615 .29648 .29571 .29599	.95605 .95596 .95588 .95579 .95571 .95663 .95554 .95545	.80985 .81012 .81040 .81068 .81095 .81128 .81178	.95079 .95070 .95061 .95052 .95043 .95083 .95024 .95015	.32639 .32667 .32694 .32722 .32749 .32777 .32804 .32832	.94523 .94514 .94504 .94495 .94485 .94476 .94466 .94457	56 55 54 53 52 51 50
4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24	.25994 .26022 .26050 .26050 .26079 .26107 .26107 .26183 .26191 .26247 .26247 .26359 .26381 .26359 .26381 .26443	.96562 .96565 .96547 .96540 .96532 .96524 .96517 .96509 .96494 .96496 .96479 .96463 .96463 .96468	.27704 .27731 .27759 .27787 .27815 .27843 .27871 .27899 .27927 .27955 .27963 .28011 .28039	.96094 .96086 .96078 .96070 .96082 .96084 .96087 .96029 .96029 .96018	.29348 .29376 .29404 .29432 .29460 .29487 .29515 .29548 .29571 .29599	.95562 .95564 .95545	.81012 .81040 .81068 .81095 .81128 .81151 .81178	.95070 .95061 .95052 .95048 .95088 .95024 .95015	.82667 .82694 .82722 .82749 .82777 .82804 .32882	.94514 .94504 .94495 .94485 .94476 .94466 .94457	56 55 54 53 52 51 50
5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24	.26022 .26050 .26079 .26107 .26185 .26185 .26191 .26219 .26219 .26217 .26351 .26359 .263587 .26445	.96565 .96547 .96540 .96532 .96524 .96517 .96509 .96503 .96494 .96496 .96479 .96471 .96463 .96463 .96464	.27704 .27731 .27759 .27787 .27815 .27843 .27871 .27899 .27927 .27955 .27963 .28011 .28039	.96096 .96078 .96070 .96062 .96054 .96046 .96087 .96029 .96021 .96018	.29376 .29404 .29432 .29480 .29487 .29515 .29548 .29571 .29599	.95562 .95564 .95545	.31040 .31068 .81095 .31123 .31151 .31178	.95061 .95052 .95043 .95083 .95024 .95015	.82694 .82722 .32749 .82777 .32804 .32832	.94504 .94485 .94485 .94476 .94466 .94457	52 51 50
7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24	.26079 .26107 .26107 .26163 .26163 .26191 .26219 .26275 .26303 .26351 .26359 .26359 .26351 .26443	.96547 .96540 .96532 .96524 .96517 .96509 .96502 .96494 .96486 .96479 .96463 .96463	.27759 .27787 .27815 .27843 .27871 .27899 .27927 .27955 .27965 .27963 .29011 .29039	.96070 .96062 .96054 .96046 .96087 .96029 .96021	.29482 .29480 .29487 .29515 .29548 .29571 .29599	.95562 .95564 .95545	.81068 .81095 .81123 .81151 .81178	.95048 .95088 .95024 .95015	.32749 .82777 .32804 .32832	.94485 .94476 .94466 .94457	52 51 50
8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24	.26107 .26185 .26163 .26191 .26219 .26217 .26275 .26308 .26351 .26359 .26387 .26443 .26471	.96532 .96524 .96517 .96509 .96503 .96494 .96486 .96479 .96463 .96456 .96448	.27787 .27815 .27843 .27871 .27899 .27927 .27955 .27963 .28011 .29039	.96062 .96054 .96046 .96087 .96029 .96021	.29460 .29487 .29515 .29548 .29571 .29599	.95562 .95564 .95545	.81123 .81151 .81178	.95088 .95024 .95015	.32777 .32804 .32832	.94476 .94466 .94457	52 51 50
9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24	.26185 .26163 .26191 .26219 .26247 .26275 .26308 .26351 .26359 .26387 .26443 .26471	.96524 .96517 .96509 .96502 .96494 .96486 .96479 .96471 .96463 .96456 .96448	.27815 .27843 .27871 .27899 .27927 .27965 .27963 .28011 .28039	.96054 .96046 .96087 .96029 .96021 .96018	.29487 .29615 .29648 .29571 .29599	.95554 .95545 .95586	.81151 .81178	.95024 .95015	.32804 .32832	.94466 .94457	51 50
10 11 12 13 14 15 16 17 18 19 20 21 22 23 24	.26163 .26191 .26219 .26247 .26275 .26308 .26331 .26359 .26387 .26443 .26443	.96517 .96509 .96502 .96494 .96486 .96479 .96471 .96463 .96456 .96448	.27843 .27871 .27899 .27927 .27955 .27963 .28011	.96046 .96087 .96029 .96021 .96018	.29515 .29548 .29571 .29599	.95545 .95586	.81178	.95015	.32832	.94457	50
12 13 14 15 16 17 18 19 20 21 22 23 24	.26219 .26247 .26275 .26308 .26351 .26359 .26387 .26443	.96502 .96494 .96486 .96479 .96471 .96463 .96456	.27899 .27927 .27955 .27963 .28011 28039	.96029 .96021 .96018	.29571 .29599		.81904		90050	94447	49
13 14 15 16 17 18 19 20 21 22 23 24	.26247 .26275 .26308 .26351 .26359 .26387 .26445 .26443	.96494 .96486 .96479 .96471 .96463 .96456	.27927 .27955 .27963 .28011 28039	.96018 I	.29599			.95006			
14 15 16 17 18 19 20 21 22 23 24	.26275 .26308 .26331 .26359 .26387 .26415 .26443	.96486 .96479 .96471 .96463 .96456 .96448	.27955 .27983 .28011 28039	.96018 I		.50040	.81288	.94997	.82887	.94438	48
15 16 17 18 19 20 21 22 23 24	.26308 .26331 .26359 .26387 .26415 .26443	.96479 .96471 .96463 .96456 .96448	.27983 .28011 28039	96005	.29626	.95519 .95511	.81261 .81289	.94988 .94979	.32914 .32942	.94428 .94418	47 46
16 17 18 19 20 21 22 23 24	.26331 .26359 .26387 .26415 .26443	.96471 .96463 .96456 .96448	.28011 28039		.29654	.95502	.81316	.94970	.82969	.94409	45
18 19 20 21 22 23 24	.26387 .26415 .26443	.96456 .96448	.28039	.95997	.29682	.95498 .95485	.81844	.94961	.32997	.94399	44
19 20 21 22 23 24	.26415 .26443	.96448		.95989	.29710	.95485	.81872	.94952	.53024	.94390	43
20 21 22 23 24	.26443	96440	.28067 .28095	.95961 .95972	.29737 .29765	.95476	.31399 .31427	.94943 .94933	.83051 .83079	.94380 .94370	42 41
22 23 24	.26471		.28123	.95964	.29798	.95467 .9545 9	.81454	.94924	.83106	.94361	40
22 23 24	98500	.96483	.28150	.95956	.29821	.95450	.81482	.94915	.33134	.94351	39
24		.96425	.28178	.95948	.29849	.95441 .95433	.81510	.94906	.83161	.94342	38
	.26528	.96417	.28206 .28234	.95940 .95931	.29876 .29904	.96433	.81587	.94897	.33189 .33216	.94332 .94322	37 36
	.26584	.96410 .96402	.28262	.96923	.29932	.95424 95475	.31565 .81598	.94888 .94878	.83216	.94322	35
26	26612	.96394	.28290	.95915	.29960	.95415 .95407	.81620	.94869	.33271	.94303	34
27	.26640 .26668	.96386	.28318	.95907	.29987	.95396 I	.31648 .81675	.94860	.33298	.94293	33
28	.26668	.96379	.28346	.95898	.80015	.95389	.81675	.94851	.83326	.94284	32
29 30	.26696 .26724	.96371 .96368	.28374 .28402	.95890 .95882	.80048 .80071	.95880 .95872	.81703 .81780	.94842 .94832	.83353 .83381	.94274 .94264	31 30
31	.26752	.96355	.28429	.95874	.30096	.95363	.81758	.94823	.33406	.94254	29
32	.26780	.96347	.28457	.95865	.30126	.95354	.81786	.94814	.33436	.94245	28
33	.26808	.96340	.28485	.95857	.30154	.95845	.81818	.94805	.33463	.94235	27
34 35	.26836	.96332	.28513	.95849	.30182	.95337	.81841	.94795	.33490	.94225 .94215	26 25
36	.26864 .26892	.96324 .96316	.28541 .28569	.95841 .95832	.80209 .80287	.95328 .95819	.31868 .31896	.94786 .94777	.33518 .33545	.94210	25 24
37	.26920	.96308	.28597	.95824	.90265	.95310	.31928	.94768	.83578	.94196	23
38	.26948	.96301	.28625	.95816	.30292	.95801	.31951	.94758	.83600 .83627	.94186 .94176	22
39 40	.26976 .27004	.96293 .96285	.28652 .28680	.95807 .95799	.30320 .30348	.95293 .95284	.31979 .32006	.94749 .94740	.83627 .83655	.94176 .94167	21 20
41	.27032	.96277	.28706	.95791	.30376	.95275	.82084	.94780	.83682	.94157	19
42	.27060	.96269	.28736	.95782	.30403	.95266	.82061	.94721	.88710	.94147	18
43	.27088	.96261	.28764	.95774	.30431	95257	.82089	.94712	.83787	.94147 .94137	17
44	.27116	.96258	.28792	.95766	.80459	.95248	.82116	.94702	.33764	.94127	16
45 46	.27144 .27172	.96246 .96238	.28820 .28847	.95757 .95749	.30486 .30514	.95240 .95231	.82144 .82171	.94693 .94684	.83792 .83819	.94118	15 14
47	.27200	.96230	.28875	.95740	.30542	.95222	.82171	.94674	.33846	.94108 .94098 .94088	13
48	.27228	.96222	.28903	.95732	.30570	.95213	.32227	.94665	.33874	.94088	12
49 50	.27256 .27284	.96214 .96206	.28931 .28959	.95724 .95715	.80597 .80625	.95204 .95195	.32254 .32282	.94656 .94646	.83901 .33929	.94078 .94068	11 10
51	.27312	.96198	.28987	.95707	.80658	.95186	.82309	.94637	.33956	.94068	9
52	.27312	.96190	.28967	.95698	.80680	.95177	.32337	.94637	.33963	.94049	8
53	.27368	.96182	.29042	.95690	.30708	.95168	.82364	.94618	.34011	.94039	7
54	.27396	.96174	.29070	.95681	.30786	.95159	.82392	.94609	.84088	.94029	6
55	.27424	.96166	.29098	.95673	.80763	.95150	.82419	.94599	.84065 .84093	.94019	5
56 57	.27452 .27480	.96158 .96150	.29126 .29154	.95664 .95656	.80791 .80819	.95142 .95183	.82447 .82474	.94590 .94580	.84098 .84120	.94009 .93999	3
58	.27508	.96142	29182	.95647	.30846	.95124	.82502	.94571	.84147	.93999	2
59	.27536	.96134	.29209	.95639	,30874	.95115	.82529	.94561	.84175	.93979	1
60	.27564	.96126	.29237	.95630	.80002	.95106	.82557	.94552	.34202	.93969	0
	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	
1	7	<u>'</u> 40	7:	<u>'</u> 30	7:	20	7	[°	70	, o	′

NATURAL SINES AND COSINES.

F		20	ρ	2	lo	2	20	2	30	2	10
l	:	Sine	Cosine								
Ŀ	1.1	84202 84229 84257	.93969 .93959 .93949	.35837 .35864 .35891	.93358 .93348 .93337	.37461 .37488 .37515	.92718 .92707 .92697	.39073 .39100 .39127	.92050 .92039 .92028	.40674 .40700 .40727	.91355 .91343 .91331
	1	34284 34311 34339	.93939 .93929 .93919	.35918 .35945 .35973	.93327 .93316 .93306	.37542 .37569 .37595	.92686 .92675 .92664	.39153 .39180 .39207	.92016 .92005 .91994	.40758 .40780 .40806	.91319 .91307 .91295
8	1:	34366 34393 34421	.93909 .93899 .93889	.36000 .36027 .36054	.93295 .93285 .93274	.37622 .37649 .37676 .37703	.92653 .92642 .92631	.39234 .39260 .39287	.91982 .91971 .91959	.40833 .40860 .40886	.91283 .91272 .91260
9 10 11	.	34448 34475 34503	.93879 .93869 .93859	.36081 .36108	.93264 .93253	.37703 .377 3 0	.92620 .92609 .92598	.39314 .39341 .39367	.91948 .91936 .91925	.40913 .40939 .40966	.91248 .91236
12 13 14		.34530 .34557 .84584	.93849 .93839 .93829	.36162 .36190 .36217	.93232 .93222 .93211	.37784 .37811 .37838	.92587 .92576 .92565	.39394 .39421 .39448	.91914 .91902 .91891	.40992 .41019 .41045	.91212 .91200 .91188
15 16 17 18		.34612 .34639 .84666 .34694	.93819 .93809 .93799 .93789	.36244 .36271 .36298 .36325	.93201 .93190 .93180 .93169	.37865 .37892 .37919 .37946	.92554 .92543 .92532 .92521	.39474 .39501 .39528 .39555	.91879 .91868 .91856 .91845	.41072 .41098 .41125 .41151	.91176 .91164 .91152 .91140
19 20		.34721 .34748	.93779 .93769	.36352 .36379	.93159 .93148	.37973 .3 7999	.92510 .92499	.39581 .39608	.91833 .91822	.41178 .41204	.91128 .91116
21 22 23 24		.34775 .34803 .34830 .34857	.93759 .93748 .93738	.36406 .36434 .36461 .36488	.93137 .93127 .93116	.38026 .38053 .38080 .38107	.92488 .92477 .92466 .92455	.39635 .39661 .39688 .39715	.91810 .91799 .91787 .91775	.41231 .41257 .41284 .41310	.91104 .91092 .91080 .91068
25 26 26		.34884 .34912	.93728 .93718 .93706 .93698	.36515 .36542 .36569	.93106 .93095 .93084 .93074	.38134 .38161 .38188	.92444 .92432 .92421	.39741 .39768 .39795	.91764 .91752 .91741	.41887 .41863 .41890	.91056 .91044 .91032
25 25 36	ÐΙ	.34966 .34993 .35021	.93688 .93677 .93667	.36596 .36623 .36650	.93063 .93052 .93042	.38215 .38241 .38268	.92410 .92399 .92388	.39822 .39848 .39875	.91729 .91718 .91706	.41416 .41443 .41469	.91020 .91008 .90996
3 3	3	.35048 .35075 .35102	.93657 .93647 .93637	.36677 .36704 .36731	.93031 .93020 .93010	.38295 .38322 .38349	.92377 .92366 .92355	.39902 .39928 .39955	.91694 .91683 .91671	.41496 .41522 .41549	.90984 .90972 .90960
1 3	5 6 7	.85130 .85157 .85184 .85211	.93626 .93616 .93606 .93596	.36758 .36785 .36812 .36839	.92999 .92988 .92978 .92967	.38376 .38403 .38430 .38456	.92343 .92332 .92321 .92310	.39982 .40008 .40035 .40062	.91660 .91648 .91636 .91625	.41575 .41602 .41628 .41655	.90948 .90936 .90924 .90911
3	8 9	.35239 .35266 .35293	.93585 .93575 .93565	.36867 .36894 .36921	.92956 .92945 .92935	.38483 .38510 .38537	.92299 .92287 .92276	.40088 .40115 .40141	.91613 .91601 .91590	.41681 .41707 .41784	.90899 .90887 .90875
- 1 4	12	.35320 .85347 .35875	.98555 .98544 .93584	.36948 .36975 .37002	.92924 .92913 .92902	.38564 .38591 .38617	.92265 .92254 .92243	.40168 .40195 .40221	.91578 .91566 .91555	.41760 .41787 .41818	.90863 .90851 .90839
	14 15 46	.85402 .85429 .85456	.93524 .93514 .93502	.37029 .37056 .37083	.92892 .92881 .92870	.38644 .38671 .38698	.92231 .92220 .92209	.40248 .40275 .40301	.91543 .91531 .91519	.41840 .41866 .41892	.90826 .90814 .90802
	47 48 49 50	.85484 .35511 .35588 .85565	.93493 .93483 .93472 .93462	.37110 .37137 .37164 .87191	.92859 .92849 .92838 .92827	.38725 .38752 .38778 .38605	.92198 .92186 .92175	.40328 .40355 .40381 .40408	.91508 .91496 .91484 .91472	.41919 .41945 .41972 .41998	.90790 .90778 .90766 .90753
١	51 52	.85592 .85619	.93452 .93441	.87218 .87245	.92816 .92805	.38832 .38859 .38886	.92152 .92141	.40434 .40461	.91461 .91449	.42024 .42051 .42077	.90741 .90729 .90717
- 1	58 54 55 56 57	.85647 .35674 .85701 .85728	.93431 .93420 .93410 .93400	.37272 .37299 .37326 .37853	.92794 .92784 .92773 .92762	.38912 .38939 .38966	.92130 .92119 .92107 .92096	.40488 .40514 .40541 .40567	.91437 .91425 .91414 .91402	.42104 .42180 .42156	.90704 .90692 .90680
1	57 58 59 60	.85755 .85782 .85810 .85837	.98389 .98379 .98368 .93358	.87880 .87407 .87484 .37461	.92751 .92740 .92729 .92718	.38993 .39020 .39046 .39073	.92085 .92073 .92062 .92060	.40594 .40621 .40647 .40674	.91890 .91378 .91366 .91355	.42183 .42209 .42235 .42262	.90668 .90655 .90643 .90631
	_	Cosine	Sine								
		6	90	68	30	6'	70	66	60	65	50

Ţ,	2	50	2	ġ°	2	70	2	80		29º	
Ĺ	Sine	Cosine									
0	.42262 .42288 .42315	.90631 .90618 .90606	.43887 .43863 .43889	.89879 .89667 .89654	.45399 .45425 .45451	.89101 .89087 .89074	.46947 .46973 .46999	.88295 .89281 .88967	.48481 .48596 .48532	.87462 .87446 .87434	
3	.42341	.90594	.43916	.89841	.45477	.89061	.47024	.88254	.48557	.87480	12
4	.42367	.90582	.43942	.89828	.45508	.89048	.47050	.88240	.49683	.87486	19
5	.42394 .42420	.90569 .90557	.43968 .43994	.89816 .89808	.45529 .45554	.89035 .89021	.47076	.88226 .88213	.48684 .48684	.87391 .87377	
7	.42446	.90545	.44020	.89790	.45580	.89008	.47101 .471 27	.88199	.49659	.97363	13
8	.42473	.90532	.44046	.89777	.45606	.88995	.47158	.88185	.48684	.87340	12
9 10	.42499 .42525	.90520 .90507	.44072 .44098	.89764 .8 9 752	.45632 .45668	.88961 .88968	.47178 .47204	.88172 .88158	.48710 .48785	.87335	222
									ł	1	-
111	.42552 .42578	.90495	.44124	.89739	.45684	.88955	.47229	.88144	.48761	.87292	1 5
12 13	.42604	.90488 .90470	.44151 .44177	.89726 .89713	.45710 .45736	.88942 .88928	.47255 .47281	.881 30 .88117	.48786 .48811	.87278	48.8
14	.42631	.90458	.44208	.89700	.45762	.88915	.47806	.86108	48827	.87264	
15	.42657	.90446	.44229	.89687	.45787	.88902	.47832	.88089	.48862	.87 264 .87 260	45
16	.42683	.90433	.44255	.89674	.45818	.88888	.47358	.88075	.48888	.87235	4
17 18	.42709 .42736	.90421 .90408	.44281 .44307	.89662 .89649	.45839 .45865	.88875	.47883 .47409	.88062 .88048	.48913 .48938	.87221 .87207	40
19	.42762	.90396	.44333	.89636	.45891	.88848	.47484	.88084	.48964	.87198	4
20	.42788	.90383	.44859	.89623	.45917	.88885	.47460	.88020	.48980	.87178	40
21	.42815	.90871	.44385	.89610	.45942	.88822	.47486	.88006	.49014	.87164	39
22	.42841	.90858	.44411	.89597	.45068	.88808	.47511	.87998	.49040	.87150	38
23	.42867	.90346	.44487	.89584	.45994	.88795	.47587	.87979	.49065	.87136	37
24 25	.42894 .42920	.90334 .90321	.44464 .44490	.89571 .89558	.46020 .46046	.88782 .88768	.47562 .47588	.87965 .87951	.49090 .49116	.87121 .87107	36
26	.42946	.90309	.44516	.89545	.46072	.88755	.47614	.87987	.49141	.87988	34
27	.42972	.90296	.44542	.89532	.46097	.88741	47639	.87923	.49166	.87079	33
28	.42999	.90284	.44568	.89519	.46123	.88728	.47665	.87909	.49192	.87064	33
29 30	.43025	.90271 .90259	.44594 .44620	.89506 .89498	.46149 .46175	.88715 .88701	.47690 .47716	.87896 .87882	.49217 .49242	.87056 .87066	31
								1		1	
31	.43077 .43104	.90246 .90233	.44646 .44672	.89480 .89467	.46201 .46226	.88688 .88674	.47741	.87868 .87854	.49268 .49293	.87021 .87007	29
33	.43130	.90233 .90221	.44698	.89454	.46252	.88661	.47767 .47793	.87840	.49293	.86993	27
34	.43156	.90208	.44724	.89441	.46278	.88647	.47818	.87826	.49344	.86978	26
35	.43182	.90196	.44750	.89428	.46304	.88634	.47844	.87812	.49369	.86964	25
36 37	.43209	.90183 .90171	.44776	.89415 .89402	.46330 .46355	.88620 .88607	.47869 .47895	.87798 .87784	.49394 .49419	.86949 .86985	24
38	.43261	90158	.44828	.89389	.46381	.88593	.47920	.87770	.49445	.86921	22
39	.43287	.90146	.44854	.89376	.46407	.88580	.47946	.87756	.49470	.86906	21
40	.43313	.90183	.44880	.89363	.46433	.88566	.47971	.87743	.49495	.86892	20
41	.43340	.90120	.44906	.89850	.46458	.88553	.47997	.87729	.49521	.86878	19
42	.43366	.90108	.44932	.89337	.46484	.88539	.48022	.87715	.49546	.86963	18
43	.43392 .43418	.90095 .90082	.44958 .44984	.89324 .89311	.46510 .46586	.88526 .88512	.48048	.87701 .87687	.49571 .49596	.86849 .86834	17 16
45	.43445	.90082	.45010	.89311 .89298	.46561	.88499	.48073	.87687	.49622	.86820	15
46	.43471	.90057	.45036	.89285	.46587	.88485	.48124	.87659	.49647	.86805	14
47	.43497	.90045	.45062	.89272	.46613	.88472	.48150	.87645	.49672	.86791	13
48 49	.43528 .43549	.90032 .90019	.45088 .45114	.89259 .89245	.46639 .46664	.88458 .88445	.48175 .48201	.87631 .87617	.49697 .49723	.86777 .86762	12 11
50	.43575	.90007	.45140	.89232	.46690	.88431	.48226	.87608	.49748	.86748	10
											٠
51 52	.43602 .43628	.89994 .89981	.45166 .45192	.89219 .89206	.46716 .46742	.88417 .88404	.48252 .48277	.87589 .87575	.49773 .49796	.86733 .86719	9
53	.43654	.89968	.45218	.89193	.46767	.88390	.48303	.87561	.49824	.86704	7
54	.43680	.89956	.45243	.89180	.46793	.88377	.48328	.87546	.49849	.86690	6
55	.43706	.89948	.45269	.89167	.46819	.88863	.48354	.87532	.49674 .49699	.86675	5
5 6	.43733 .43759	.89930 .89918	.45295 .45321	.89158 .89140	.46844 .46870	.88349 .88336	.48379 .48405	.87518 .87504	.49999	.86646	4 3
58	.43785	.89905	.45347	.89127	.46896	.88322	.48430	.87490	.49960	.88682	2
59	.48811	.89892	.45373	.89114	.46921	.88808	.48456	.87476	.49975	.86617	1
60	.43837	.89879	.45899	.89101	.46947	.88296	.48481	.87462	.50000	.86608	0
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	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Stne	
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1	64	0	63	p	62	.0	61	lo	60	yo	- 1
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NATURAL SINES AND COSINES.

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	30	yo	37	lo	35	2º	33	30	3-	t o
*	Sine	Cosine								
9	.50000	.86603	.51504 .51529	.85717 .85702	.52992 .53017	.84805 .84789	.54464 .54488	.83867 .83651	.55919 .55943	.82904 .82887
	.50050	.86573	.51554	.85687	.53011	.84774	.54513	.83835	MARK	.82871
. 3	.50976	.84559	.51579	85672	.58066	.84759	.54537	.83619	.55992	.82855
4	.50101	.86544	.51604	.85657	.53091	.84748	.54561	.88804	.56016	.82889
5	.50126 .50151	.86530 .86515	.51628 .51653	.85642 .85627	.53115 .53140	.84728 .84712	.54586 .54610	.83788 .83772	.56040 .56064	.82822 .82806
- 7	.50176	.86501	.51678	.85612	.58164	.84697	.54635	.88756	.56088	.82790
8	.50201	.86486	.51703	.85597	.53189	.84681	.54659	.88740	.56112	.82773
9	.50227	.86471 .86457	.51728	.85582	.58214	.84666	.54683	.83724	.56136	.82757
10	.50252	.86457	.51753	.85567	.58238	.84650	.54708	.88708	.56160	.82741
11	.50277	.86442	.51778	.85551	.53263	.84635	.54732	.88692	.56184	.82724
12	.50302	.86427	.51808	.85536	.53288	.84619	.54756 .54781	.83676	.56208	.82708
18 14	.50327 .50352	.86413	.51828 .51852	.85521 .85506	.53312	.84604 .84588	.54805	.88660 .88645	.56232 .56256	.82692 .82675
15	.50377	86384	.51877	.85491	.53361	.84573	.54829	.88629	.56280	.82659
16	.50403	.86869	.51902	.85476	.53386	.84557	.54854	.83613	.56805	.82643
17	.50428	.86354	.51927	.85461	.58411	.84542	.54878	.83597	.56829	.82626
18	.50453	.86340 .86325	.51952 .51977	.85446 .85431	.53435 .53460	.84526 .84511	.54902 .54927	.83581	.56858 .56877	.82610
19 20	.50478 .50503	.86325	.52002	.85416	.53484	.84011 .84495	.54927 .54951	.83565 .83549	.56401	.82593 .82577
	****			05.403						
21 22	.50528 .50553	.86295 .86281	.52026 .52051	.85401 .85885	.58509 .58534	.84480 .84464	.54975 .54999	.88533 .88517	.56425 .56449	.82561 .82544
23	.50578	.86266	.52076	.85370	.53558	.84448	.55024	.88501	.56473	.82528
24	.50603	.86251	.52101	.85355	.53583	.84433	.55048	.88485	.56497	.82511
25	.50628 .50654	.86237	.52126	.85840	.53607	.84417	.55072	.88469	.56521	.82495
26 27	.50679	.86222 .86207	.52151 .52175	.85325 .85310	.58632 .58656	.84402 .84386	.55097 .55121	.83453 .83437	.56545 .56569	.82478 .82462
28	.50704	.86192	.52200	.85294	.53681	.84870	.56145	.83421	.56593	.82446
29	.50729	.86178	.52225	.85279	.53705	.84355	,55169	.83405	.56617	,82429
30	.50754	.86163	.52250	.85264	.58780	.84339	.55194	.88889	.56641	.82413
31	.50779	.86148	.52275	.85249	.58754	.84324	.55218	.83373	.56665	.82396
32	.50804	.86133	.52299	.85234	.58779	.84808	.55242	.83356	.56689	.82380
33 34	.50829 .50854	.86119 .86104	.52824	.85218 .85203	.58804 .58828	.84292 .84277	.55266 .55291	.88340 .83324	.56713 .56736	.82363 .82347
35	.50879	.86089	.52874	85188	.53853	.84261	.65315	.83808	.56760	.82880
36	.50904	.86074	.52399	.85178	.53877	.84245	.55339	.88292	.56784	.62314
37 38	.50929 .50954	.86059 .86045	.52428	.85157	.53902 .53926	.84230	.55363	.88276	.56808	.82297
39	.50979	88030	.52448 .52478	.85142 .85127	.58926	.84214 .84198	.55388 55419	.88260 .88244	.56832	.82261 .82264
40	.51004	.86030 .86015	.52498	.85112	.58975	.84182	,55412 ,55436	.83228	.56880	.82248
41	.51029	.86000	.52522	.85096	.54000	.84167	.55460	.83212	.56904	.82281
42	.51054	.85985	.52547	.85081	.54024	.84151	.55484	.88195	.56928	.82214
43	.51079	.85970	.52572	.85066	.54049	.84135	.55509	.88179	.56952	.82198
44 45	.51104 .51129	.85956 .85941	.52597 .52621	.85051 .85035	.54073	.84120 .84104	.55533 .55557	.88163	.56976	.82181
46	.51154	.85926	.52646	.85020	.54122	.84088	.55581	.88147 .88131	.57000 .57024	.82165 .82148
47	.51179	.85911	.52671	.85005	.54146	.84072	.55605	.88115	.57047	82132
48	.51204	.85896	.52696	.84989	.54171	.84057	.55630	.83098	.57071	.82115
49 50	.51229 .51254	.85881 .85866	.52720 .52745	.84974 .84959	.54195 .54220	.84041 .84025	.55654	.83082	.57095	.82098
							.556 78	.83066	.57119	.82082
51	.51279	.85851	.52770	.84943	.54244	.84009	.55702	.88050	.57143	.82065
52 53	.51304 .51329	.85836 .85821	.52794 .52819	.84928 .84913	.54269 .54293	.83994 .83978	.55726	.88084	.57167	.82048
54	.51854	.85806	.52844	.84897	.54817	.83978	.55750 .55775	.88017 .88001	.57191 .57215	.82032 .82015
55	.51879	.85792	.52869	.84882	.54842	.83946	55799	.82985	57238	,81999
56		.85777	.52893	.84866	.54866	.83930	.55823	.82969	.57262	.81982
57	.51429	.85762	.52918	.84851	.54391	.83915	.55847	.82953	.57286 .57310	.81965
58 59	.51464 .51479	.85747 .85732	.52943 .52967	.84836 .84820	.54415 .54440	.83899 .83883	.55871 .55895	.82936 .82920	.57310	.81949 .81932
60	.51504	.85717.	.52992	.84805	.54464	.83867	.55919	.82920 .82904	.57334 .57358	.81932 .81915
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	Cosine	Sine								
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'		2 0.	58	20	5'	70		20	5.5	:0
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NATURAL SINES AND COSINES.

35	50	36	30	3'	70	3	80	3	9°	
Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	1
.57358	.81915	.58779	.80902	.60182	.79864	.61566	.78801	.62932	.77715	60
.57881	.81899	.58802	.80885	.60205	.79846	.61589	.78783	.62955	.77696	
.57405	.81882	.58826	.80667	.60228	.79829	.61612	.78765	.62977	.77678	58
.57429	.81865	.58849 .58873	.80650	.60251	.79811	.61635	.78747	.63000 .63022	.77660	57
.57453 .57477	.81848 .81832	.58896	.80833 .80816	.60274 .60298	.79793 .79776	.61658 .61681	.78729 .78711	.63045	.77641 .77623	56 56
57501	.81815	.58920	.80799	.60321	.79758	.61704	.78694	.63068	.77605	54
57524	.81798	.58943	.80782	.60344	.79741	.61726	.78676	.63090	.77586	54 53
.57548	.81782	,58967	.80765	.60367	.79728	.61749	78658	.63113	.77568	52
.57572	.81765	.58990	.80748	.60390	.79706	.61772	.78640	.63135	.77550	51
.57596	.81748	.59014	.80730	.60414	.79688	.61795	.78622	.63158	.77581	50
.57619	.81731	.59037	.80713	.60437	.79671	.61818	.78604	.63180	.77513	49
.57643	.81714	.59061	.80696	.60460	.79653	.61841	.78586	.63203	.77494	48
.57667	.81698	.59084	.80679	.60483	.79635	.61864	.78568	.63225	.77476	47
.57691 .57715	.81681 .81664	.59108 .59131	.80662 .80644	.60506 .60529	.79618 .79600	.61887 .61909	.78550 .78532	.63248 .63271	.77458 .774 39	45
.57738	.81647	.59154	.80627	.60553	.79583	.61932	.78514	.63293	.77421	44
.57762	.81631	.59178	.80610	.60576	.79565	.61955	.78496	.63316	.77402	43
.57786	.81614	.59201	.80593	.60599	.79547	.61978	.78478	.63338	.77384	42
.57810	.81597	.59225	.80576	.60622	.79530	.62001	.78460	.63361	.77366	41
.57833	.81580	.59248	.80558	.60645	.79512	.62024	.78442	.63383	.77347	40
.57857	.81563	.59272	.80541	.60668	.79494	.62046	.78424	.63406	.77329	39
.57881	.81546	.59295	.80524	.60691	.79477	.62069	.78405	.63428	.77810	38
.57904	.81530	.59318	.80507	.60714	.79459	.62092	.78387	.63451	.77292	37
.57928	.81513	.59342	.80489	.60738	.79441	.62115	.78369	.63473	.77273	36
.57952	.81496	.59365 .59389	.80472	.60761	.79424	.62138	.78351 .78333	.63496 .63518	.77255	35
.57976 .57999	.81479 .81462	.59412	.80455 .80438	.60784 .60807	.79406 .79388	.62160 .62183	.78315	.68540	.77236 .77218	34 33
.58023	.81445	.59436	.80420	.60830	.79371	.62206	.78297	.68563	.77199	32
.58047	.81428	.59459	.80403	.60853	.79353	.62229	.78279	.63585	.77181	31
.58070	.81412	.59482	.80386	.60876	.79335	.62251	.78261	.63608	.77162	30
.58094	.81395	.59506	.80368	.60899	.79318	.62274	.78243	.63630	.77144	29
.58118	.81378	.59529	.80351	.60922	.79300	.62297	.78225	.63653	.77125	28
.58141	.81361	.59552	.80334	.60945	.79282	.62320	.78206	.63675	.77107	27
.58165	.81344	.59576	.80316	.60968	.79264	.62342	.78188	.63698	.77088	26
.58189 .58212	.81327 .81310	.59599 .59622	.80299 .80282	.60991 .61015	.79247 .79229	.62365 .62388	.78170 .78152	.63720 .63742	.77070 .77051	25 24
.58236	.81293	.59646	.80264	.61038	.79229	.62411	.78134	.63765	.77033	23
.58260	.81276	.59669	.80247	.61061	.79193	.62433	.78116	.63787	.77014	22
.58283	.81259	.59693	.80230	.61084	.79176	.62456	.78098	.63810	.76996	21
.58307	.81242	.59716	.80212	.61107	.79158	.62479	.78079	.63832	.76977	20
.58330	.81225	.59739	,80195	.61130	.79140	.62502	.78061	.63854	.76959	19
.58354	.81208	.59763	.80178	.61153	.79122	.62524	.78043	.63877	.76940	is
.58378	.81191	.59786	.80160	.61176	.79105	.62547	.78025	.63899	.76921	17
.58401	.81174	.59809	.80148	.61199	.79087	.62570	.78007	.63922	.76903	16
.58425	.81157	.59832 .59856	.80125	.61222	.79069	.62592	.77988 .77970	63944 63966		15
.58449 .58472	.81140 .81123	.59879	.80108 .80091	.61245 .61268	.79051 .79033	.62615 .62638	.77970	.63989		14
.58496	.81106	.59902	.80078	.61291	.79016	.62660	.77934	.64011		12
.58519	,81089	.59926	.80056	.61314	.78998	.62683	.77916	.64033	.76810	ii l
.58543	.81072	.59949	,80038	.61337	.78980	.62706	.77897	.64056	.76791	10
.58567	.81055	.59972	.80021	.61360	.78962	.62728	.77879	.64078	.76772	9
.58590	.81038	.59995	.80003	.61383	.78944	.62751	.77861	.64100	.76754	8
.58614	.81021	.60019	.79986	.61406	.78926	.62774	.77843	.64123	.76735	7
.58637	.81004	.60042	.79968	.61429	.78908	.62796	.77824	.64145	.76717	6
.58661	.80978	.60065 .60089	.79951 .79934	.61451	.78891 .78873	.62819 .62842	.77806 .77788	.64167	.76698	5
.58684 .58708	.80970 .80953	.60112	.79916	.61474 .61497	.78855	.62864	.77769	.64190 .64212	.76679 .76661	4 3
.58731	.80936	.60135	79899	.61520	.78837	.62887	.77751	.64234	.76642	2
.58755	,80919	.60158	.79881	.61543	.78819	.62909	.77733	.64256	.76623	i l
.58779	.80902	.60182	.79864	.61566	.78801	.62932	.77715	.64279	.76604	۰
Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	
		-	1	-	1	-	-	-		,
5	40	5	30	5	20	5	10	50	00	
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1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	40	p	4	1°	4	20	4	30	4	40
	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosin
1	.64279	.76604	.65606	.75471	.66913	.74314	.68200	.73185	.69466	.71984
3	.64301 .64328	.76586 .76567	.65628 .65650	.75452 .75433	.66935 .66956	.74295 .74376	.68221 .68242	.73116 .73096 .73076	.69487 .69508	.71914 .71894
3 4 5	.64346 .64368 .64390	.76548 .76530	.65672 .65694	.75433 .75414 .75895 .75875 .75856 .75887	.66978 .66999	.74256	.68264	.78076 78056	.69529	.71873 .71853
5	.64390	.76511	.65716	.75375	.67021	.74237 .74217 .74198	.6828ŏ .68306	.73056 .73086	.69549 .69570	.71833
6	.64412 .64435	.76492 .76473	.65738 .65759	.75356 .75337	.67043 .67064	.74198	.68327 .68349	.73016 .72996 .72976	.69591 .69612	.71813 .71792
8	.64457	.76455	.65781	.75518	.67086	.74159	.68370	.72976	.69688	.71772
10	.64457 .64479 .64501	.76455 .76436 .76417	.65803 .65825	.75299 .75280	.67107 .67129	.74139 .74120	.68391 .68412	.72957 .72937	.69654 .69675	.71752 .71782
11	.64524 .64546	.76398	.65847	.75261	.67151	.74100 .74080	.68434	.72917	.69696	.71711
12 18	.64568 .64590	.76380 .76361 .76342	.65869 .65891	.75241 .75222 .75203	.67172 .67194	.74080	.68455 .68476	.72897 .72877	.69717 .69787	.71691 .71671
14	.64590	.76342	.65913	.75203	.67215 .67237	.74061 .74041 .74022	.68476 .68497 .68518	.72857	.69787 .69758 .69779	.71650
14 15 16 17	.64612 .64635	.76323 .76304 .76286	.65935 .65956	.75184 .75165	6725R	74002	68539	.72837 .72817	.69779	.71630 .71610
17	84857	.76286	.65978	75146	.67280 .67 3 01	73963	.68561	.72817 .72797	.69821	.71610 .71590
18	.64679 .64701 .64723	.76267 .76248	.66000 .66022	.75126 .75107	.67301 .67328	.78963 .78944	.68582 .68603	.72777	.69842 .69862	.71569 .71549
20	.64723	1	.66044	.75088	.67323 .67344	.73924	.68624	.72757 .72787	.69883	.71529
21	.64746	.76210	.66066 .66088	.75069	.67366	.73904	.68645	.72717	.69904	.71508
22 23	.64768 .84790 .64812	.76192 .76173	.66109	.75050 .75030	.67387 .67409	.73885 .73865	.68666 .68688	.72697 .72677	.69925 .69946	.71488 .71468
34	.64812	.76154 .76135	.66131 .66153	.75011 .74992	.67409 .67430	.73846	.68709	.72657	.69966	.71447
25 26	.64856	1 76116	.66175	.74973	.67452 .67473	.73826 .73806	.687 3 0 .68751	.72687 .72617	.69987 .70008	.71427 .71407
27	.64878	.76097	.66197	.74958	67495	73787	.68772 .68793	.72597	.70029	.71386
28 29	.64901	76059	.66218 .66240	.74934 .74915	.67516 .67538	.73767 .73747	.68793 .68814	.72577 .72557	.70049 .70070	.71866 .71845
30	1	.76041	.66262	.74896	.67559	.73728	.68885	.72587	.70091	.71325
31		2 76003	.66284 .66306	.74876	.67580 .67602	.73708 .73688	.68857 .68878	.72517 .72497	.70112 .70132	.71305 .71284
1 32	.6501	.76003 1 .75984	66327	.74857 .74838	67623	.73669	68899	.72477	.70153	.71264
34	.6501 .6503 .6505	3 .75965 5 .75946	.66349 .66371		.67645 .67666	.73649 .73629	.68920 .68941	.72457 .72437	.70174 .70195	.71248
3	. 6507		.66393	.74799 .74780 .74760	. 6768 8	.73610 .73590	.68962	.72417	.70195	.71223 .71203
3	7 .6510	0 .75908	.66414	.74760 .74741	.67709 .67730	.73590 .73570	.68983 .69004	.72397 .72377	.70236 .70257	.71182
3	.6514	4 .75870	.66436 .66458	74722	.67752	78551	.69025	.72357	.70277	.71162 .71141
14	- 1	i '	.66480	.74703	.67773	.73581	.69046	.72887	.70298	.71121
	1 .6518 2 .6521	8 .75832 0 .75813	.66501 .66523	.74683 .74664	.67795 .67816	.78511 .78491	.69067 .69088	.72317 .72297	.70319 .70339	.71100 .71080
-14	3 .6523	2 .75794	.66545	.74644	.67837	.78491 .78472	.69109	.72277	.70360	.71059
	4 .6525 5 .6527	4 .75775 6 .75756	.66566 .66588	.74625 .74606	.67859 .67880	.73452 .73432	.69180 .69151	.72257 .72236	.70381 .70401	.71039 .71019
- 14	4590	NO 1 75799	66610	.74606 .74586	.67901 .67923	.73413	.69172	.72216	.70422 .70443	.70998
-13	17 .6532 18 .6534 19 .6536 50 .6538	0 .75719 2 .75700	.66632 .66653	.74567 .74548	.67923 .67944	.73393	.69193 .69214	.72196 .72176	.70443	.70978 .70957
- 1.	6536	75680 6 .75661	.66675	.74528	.67965	.73353	.69235	.72156	.70484	.70937
1			.66697	.74509	.67987	.73333	.69256	.72136	.70505	.70916
Į.	51 .6540 52 .6548	0 .75623	.66718 .66740	.74489 .74470	.68008 .68029	.78314 .78294	.69277 .69298	.72116 .72095	.70525 .70546	.70896 .70875
ı	58 .6545	2 .75604	.66762	.74470 .74451	.68029 .68051	.73274	.69298 .69319	.72075	.70546 .70567	.70855
- 1	54 .6547 55 .6549	4 .75585 6 .75566	.66783 .66805	.74431 .74412	.68072 .68093	.78254 .78234	.69340 .69861	.72055 .72035	.70587 .70608	.70834 .70813
- 1	56 .6551	8 .75547	.66827	.74392	.68115	.73215	.69382	.72015	.70628	.70793
١	57 .6554 58 .6556	2 .75509	.66848 .66870	.74878 .74858	.68136 .68157	.78195 .78175	.69403 .69424	.71995 .71974	.70649 .70670	.70772 .70752
-	59 .6558 60 .6560	4 .75490	.66891 .66913	.74834 .74814	.68179	.73155 .73135	.69445 .69466	.71954	.70 69 0	.70781
-					.00200	.10100		.,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,		
١	Cosin	ne Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine
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_	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	1 -
0	.00000	Infin.	.01746	57.2900	.03492	28.6363	.05241	19.0811	.06993	14.3007	
1 2	.00029	3437.75 1718.87	.01775 .01804	56.8506 55.4415	.03521 .03550	28.3994 28.1864	.05270 .05299	18.9755 18.8711	.07022 .07051	14.2411	
3	.00087	1145.92	01833	54.5613	.03579	27.9872	.65328	18.7678	.07680	14 1985	57
4	.00116	859.436	.01862	58.7086	.03609	27.7117	.05357	18.6656	.07110	14.0655 14.0079	
5	.00145	687.549	.01891	52.8821	.03638	27.4899	.05387	18.5645	.07189	14.0079	55 54 53
6	.00175	572.957 491.106	.01920 .01949	52.0807	.03667 .03696	27.2715	.05416	18.4645	.07168	13.9507	54
8	.00233	429.718	.01978	51.3032 50.5485	.03725	27.0566 26.8450	.05445	18.3655 18.2677	.07197 .07227	13,8940 13,8378	52
9	.00262	381.971	.02007	49.8157	.08754	26.6367	.05503	18.1708	.07256	13.7821	51
10	.00291	843.774	.02036	49.1039	.03783	26.4816	.05533	18.0750	.07285	18,7267	50
11	.00820	812.521	.02066	48.4121	.03812	26.2296	.05562	17.9802	.07314	13.6719	49
12 13	.00349	286.478 264.441	.02095 .02124	47.7895 47.0853	.03842 .03871	26.0307 25.8348	.05591	17.8863	.07344 .07373	13.6174 13.5634	48
14	.00407	245.562	.02158	46.4489	.08800	25.6418	.05649	17.7934 17.7015	.07402	13,5098	46
15	.00436	229.182	.02182	45.8294	.03929	25.4517	.05678	17.6106	.07481	13,4566	45
16	.00465	214.858	.02211	45.2261	.03958	25.2644	.05708	17.5205	.07461	13.4039	44
17	.00495	202.219 190.984	.02240	44.6386	.03987	25.0798	.05737	17.4814	.07490	13.3515	43
19	.00553	180.932	.02298	44.0661 43.5081	.04016	24.8978 24.7185	.05766 .05795	17.8482 17.2558	.07519 .07548	13.2996 13.2480	42
20	.00582	171.885	.02328	42.9641	.04075	24.5418	.05824	17.1693	.07578	13.1969	40
21	.00611	163.700	.02357	42.4835	.04104	24.3675	.05854	17.0837	.07607	18,1461	30
22	.00640	156.259	.02386	41.9158	.04133	24.1957	.05883	16,9990	.07636	13.0958	38
23 24	.00669	149.465 143,237	.02415	41.4106	.04162 .04191	24.0263 28.8593	.05912	16.9150	.07665	13.0458	87
25	.00727	187.507	.02473	40.4858	.04191	28.6945	.05941 .05970	16.8319 16.7496	.07 69 5 .07724	12.9962 12.9469	36 35
26	.00756	132,219	.02502	39.9655	.04250	23,5321	.05999	16.6681	.07753	12.8961	34
27	.00785	127.821	.02531	39.5059	.04279	23.3718	.06029	16.5874	.07782	12.8496	33
28	.00815	122.774	.02560	39.0568	.04308	23.2137	.06058	16.5075	.07812	12.8014	32
29 30	.00844	118.540 114.589	.02589 .02619	88.6177 38.1885	.04337	23.0577 22.9038	.06087 .06116	16.4283 16.3499	.07841 .07870	12.7586 12.7062	31
31	.00902	110.892	****								1
31	.00902	107.426	.02648 .02677	37.7686 37.3579	.04395 .04424	22.7519 22.6020	.06145 .06175	16.2722 16.1952	.07899	12.6591	29 28
88	.00960	104.171	.02706	36.9560	.04454	22.4541	.06204	16.1190	.07958	12,6124	27
34	.00989	101.107	.02735	36.5627	.04483	22.3081	.06233	16.0435	.07987	12.5199	26
35	.01018	98.2179	.02764	36.1776	.04512	22.1640	.06262	15.9687	.08017	12,4742	25
36 37	.01047	95.4895 92.9085	.02793 .02822	35.8006 35.4313	.04541 .04570	22.0217 21.8813	.06291	15.8945 15.8211	.08046	12.4288 12.3838	24
38	.01105	90.4633	.02851	35.0695	.04599	21.7426	.06850	15.7483	.06104	12,3890	23
39	.01185	88.1436	.02881	34.7151	.04628	21.6056	.06379	15.6762	.06134	12.2946	21
40	.01164	85.939 8	.02910	84.86 78	. 046 58	21.4704	.06408	15.6048	.08163	12.2505	20
41	.01193	83.8435	.02989	34.0273	.04687	21.3369	.06437	15.5340	.06192	12.2067	19
42 43	.01222	81.8470 79.9434	.02968 .02997	33.6935 33.3662	.04716	21.2049	.06467	15.4638	.08221	12.1632	18
44	.01280	78.1263	.08026	33.3662 33.0452	.04745	21.0747 20.9460	.06496	15.8948 15.8254	.08251	12.1201 12.0772	17
45	.01809	76.3900	.03055	32.7803	.04808	20.8188	.06554	15.2571	.08309	12.0346	15
46	.01338	74.7292	.03084	32.4213	.04833	20.6932	.06584	15.1898	.08339	11.9923	14
47 48	.01367	78.1390 71.6151	.03114	32.1181 31.8205	.04862 .04891	20.5691	.06613	15.1222	.08368	11.9504	13
49	.01425	70.1533	.03143	31.5284	.04891	20.4465	.06642	15.0557 14.9898	.08397	11.9087 11.8673	12
50	.01455	68.7501	.08201	31.2416	.04949	20.3255	.06700	14.9244	.08456	11.8262	10
51	.01484	67.4019	.03230	30.9599	.04978	20.0872	.06730	14.8596	.06485	11.7853	9
52	.01518	66.1055	.03259	30.6833	.05007	19.9702	.06759	14.7954	.06514	11.7448	8
53	.01542	64.8580	.03288	30.4116	.05037	19.8546	.96788	14.7317	.06544	11.7045	7
54 55	.01571	63.6567 62.4992	.08317 .03346	30.1446 29.8823	.05066 .05095	19.7403 19.6273	.96817 .96847	14.6685 14.6059	.06573	11.6645	6
56	.01629	61.3829	.03376	29.6245	.05124	19.5156	.06876	14.5438	.08602	11.6348 11.5653	5
57	.01658	60.3058	.08405	29.3711	.05153	19.4051	.96905	14.4823	.08661	11.5461	3
58	.01687	59.2659	.08434	29.1220	.05182	19.2959	.06934	14.4212	.00690	11.5072	2
59 60	.01716 .01746	58.2612 57.2900	.08463 .08492	28.8771 28.6363	.05212 .05241	19.1879 19.0811	.96963 .06993	14.8607	.06720 .06749	11.4685 11.4801	1
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•	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	′
0	.08749	11.4301	.10510	9.51436	.12278	8.14435	.14054	7.11537	.15838	6.31375	60
1	.06778	11.8919 11.8540	.10540 .10569	9.48781 9.46141	.12308 .12338	8.12481 8.10536	.14084 .14113	7.10088 7.08546	.15868 .15898	6.30189 6.29007	59 58
3	.08837	11.8163	.10599	9.48515	.12867	8.08600	.14148	7.07059	.15928	6.27829	57
5	.08866	11.2789	.10628	9.40904	.12397	8.06674	.14178	7.05579	.15958	6.26655	56
5	.08895 .08925	11.2417	.10657 .10687	9.38307 9.35724	.12426 .12456	8.04756 8.02848	.14202 .14232	7.04105 7.02637	.15988 .16017	6.25486 6.24321	55 54
6 7	.08954	11.1681	.10716	9.33155	.12485	8.00948	.14262	7.01174	.16047	6.23160	58
8	.08954 .08983	11.1816	.10746	9.30599	.12515	7.99058	.14291	6.99718	.16077	6.22003	52
10	.09013 .09042	11.0954 11.0594	.10775 .10805	9.28058 9.25680	.12544 .12574	7.97176 7.95302	.14321 .14351	6.96268 6.96823	.16107 .16137	6.20851 6.19703	51 50
11	.09071	11.0237	.10634	9.23016	.12608	7.98438	.14381	6.95885	.16167	6.18559	49
12	.09101	10.9682 10.9529	.10863	9.20516	.12633	7.91582	.14410	6.93952	.16196	6.17419	48
13 14	.09159	10.9539	.10893 .10922	9.18028 9.15554	.12662 .12692	7.89734 7.87895	.14440 .14470	6.92525 6.91104	.16226 .16256	6.16283 6.15151	47 46
15	.09189	10.8829	.10952	9.18093	.12722	7.86064	.14499	6.89688	.16286	6.14023	45
16	.09218	10.8483	.10981	9.10646	.12751	7.84242	.14529	6.88278	.16316	6.12899	44
17 18	.09247	10.81 39 10.7797	.11011 .11 04 0	9.08211 9.05789	.12781 .12810	7.82428 7.80622	.14559 .14588	6.86874 6.85475	.16346 .16376	6.11779 6.10664	43 42
19	.09906	10.7457	.11070	9.08879	.12840	7.78825	.14618	6.84082	.16406	6.09552	41
20	.09335	10.7119	.11099	9.00963	.12869	7.77035	.14648	6.92694	.16485	6.08444	40
21	.09865 .09894	10.6783 10.6450	.11128	8.98596 8.96227	.12899 .12929	7.75254	.14678	6.81812	.16465	6.07340	39
22 23	.00423	10.6118	.11158 .11187	8.93867	.12929	7.78480 7.71715	.14707 .14737	6.79936 6.78564	.16495 .16525	6.06240 6.05143	38 37
24	.09458	10.5789	.11217	8.91520	.12988	7.69957	.14767	6.77199	.16555	6.04051	36
25	.09482	10.5463	.11246	8.89185	.13017	7.68208	.14796	6.75838	.16585	6.02962	35
26 27	.09511 .09541	10.5136 10.4813	.11276 .11305	8.86862 8.84551	.13047 .13076	7.66466 7.64732	.14826 .14856	6.74483 6.73133	.16615 .16645	6.01878 6.00797	34 33
28	.09570	10.4491	.11885	8.82252	.13106	7.63005	.14886	6.71789	.16674	5.99720	32
29	.09600	10.4172	.11364	8.79964	.13136	7.61287	.14915	6.70450	.16704	5.98646	31
30	.09629	10.8854	.11894	8.77689	.18165	7.59675	.14945	6.69116	.16734	5.97576	30
31 32	.00658 .00688	10.3538 10.3224	.11423 .11452	8.75425 8.78172	.13195	7.57872	.14975 .15005	6.67787	.16764	5.96510	29
33	.09717	10.2913	.11482	8.70931	.13254	7.56176	.15006	6.66463 6.65144	.16794 .16824	5.95448 5.94390	28 27
34	.09746	10.2602	.11511	8.68701	.13284	7.52806	.15064	6.63831	.16854	5.98335	26
35 36	.09776	10.2294	.11541	8 66482	.13313	7.51132	.15094	6.62523	.16884	5.92283	25
36	.09834	10.1988 10.1683	.11570 .11 60 0	8.64275 8.62078	.13343 .18372	7.49465 7.47806	.15124 .15158	6.61219 6.59921	.16914 .16944	5.91236 5.90191	24 23
38	.09864	10.1381	.11629	8.59693	.13402	7.46154	,15183	6.58627	.16974	5.89151	22
39 40	.09693	10.1080 10.0780	.11659 .11688	8.57718 8.55555	.13482	7.44509 7.42871	.15213 .15243	6.57339 6.56055	.17004 .17033	5.88114 5.87080	21 20
41	.09952	10.0483	.11718	8.53402	.13491	7.41240	.15272	6.54777	.17063	5.86051	19
42	.09981	10.0187	.11747	8.51259	.18521	7.39616	.15302	6.53503	.17093	5.85024	18
43 44	.10011 .10040	9.96931 9.96007	.11777 .11806	8.49128 8.47007	.18550 .18580	7.37969	.158 32 .158 62	6.52234 6.50970	.17123 .17153	5.84001 5.82982	17
45	.10069	9.93101	.11836	8.44896	.13609	7.34786	.15891	6.49710	.17158	5.81966	16 15
46	.10099	9.90211	.11965	8.42795	.13639	7.33190	.15421	6.48456	.17213	5.80953	14
47 48	.10128 .10158	9.87838 9.84482	.11895 .11924	8.40705 8.38625	.13669 .136¥8	7.31600 7.30018	.15451	6.47206	.17243	5.79944	13
49	.10136	9.81641	.11954	8.36555	.13728	7.28442	.15481 .15511	6.45961	.17273	5.78938 5.77936	12 11
50	.10216	9.78817	.11983	8.34496	.13758	7.26873	.15540	6.43484	.17333	5.76937	10
51	.10246 .10275	9.76009 9.78217	.12013	8.32446	.13787	7.25810	.15570	6.42253	.17363	5.75941	9
52 53	.10275	9.78217	.12042	8.30406 8.28376	.13817 .13846	7.23754 7.22204	.15600 .15630	6.41026 6.39804	.17393 .17423	5.74949 5.73960	8
54	.10834	9.67680	.12101	8.26355	.13876	7.20661	.15660	6.38587	.17453	5.72974	6
55	.10863	9.64935	.12131	8.24345	.13906	7.19125	.15689	6.37374	.17483	5.71992	5
56 57	.10698	9.62205	.12160 .12190	8.22344 8.20352	.13985 .13965	7.17594 7.16071	.15719	6.36165	.17513	5.71013	3
58	.10452	9.56791	.12219	8.18370	.13995	7.14553	.15749 .15779	6.33761	.17543 .17573	5.70037 5.69064	2
59	.10481	9.54106	.12249	8.16398	.14024	7.13042	.15809	6.32566	.17603	5.68094	1
60	.10610	9.51436	.12278	8.14435	.14054	7.11537	.15838	6.31375	.17633	5.67128	0
	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	
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Ĺ	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.17633 .17663	5.67128 5.66165	.19438 .19468	5.14455 5.18658	.21256 .21286	4.70463 4.69791	.23087 .23117	4.33148 4.32573	.24933 .24964	4.01078 4.00582	50
1 2	.17693	5.65205	.19498	5.12862	.21316	4.69121	.23117	4.32001	.24995	4.00086	58
3	.17728	5.64248	.19529	5.12069	.21347	4.68452	.23179	4.31430	.25026	3.99592	57
i 4	.17753	5.63295	.19559	5.11279	.21377	4.67786	.23209	4.30860	.25056	3.99099	56 55
5	.17783	5.62344 5.61397	.19589 .19619	5.10490 5.09704	.21408 .21438	4.67121	.23240	4.30291	.25087	3.98607 3.98117	55
6 7	.17843	5.60452	.19649	5.08921	,21469	4.66458	.28271 .28301	4.29724 4.29159	.25118 .25149	3.97627	54 53 52
l ė	.17873	5.59511	.19680	5.08139	.21499	4.65138	.23332	4.28595	.25180	3.97139	52
9	.17903	5.58573	.19710	5.07360	.21529	4.64480	.23363	4.28032	.25211	3.96651	: 51
10	.17933	5.57638	.19740	5.06584	.21560	4.63825	.23398	4.27471	.25242	3.96165	50
11	.17963	5.56706	.19770	5.05809	.21590	4.63171	.23424	4.26911	.25273	3.95680	49
12 13	.17993 .18028	5.55777 5.54851	.19801 .19831	5.05037 5.04267	.21 6 21 .21 6 51	4.62518	.23455 .23485	4.26352 4.25795	.25304	3.95196 3.94713	48
18	.18028	5.53927	19861	5.03499	.21631	4.61219	.23485	4.25239	.25366	3.94713	46
15	,18083	5.53007	.19891	5.02734	.21712	4.60572	.23547	4.24685	.25397	3.93751	45
16	.18113	5.52090	.19921	5.01971	.21743	4.59927	.23578	4.24132	.25428	3.93271	44
17	.18143	5.51176	.19952	5.01210	.21773	4.59283	.23608	4.23580	.25459	3.92793	43
18	.18173	5.50264	.19982	5.00451	.21804	4.58641	.23639	4.23030	.25490	3.92316	42
19 20	.18203 .18233	5.49356 5.48451	.20012 .20042	4.99695 4.98940	.21834 .21864	4.58001 4.57863	.23670 .23700	4.22481 4.21933	.25521 .25552	3.91839 3.91364	41
									1		
21	.18263	5.47548	.20073	4.98188	.21895	4.56726	.23731	4.21387	.25583	3.90890	39
22 23	.18293	5.46648 5.45751	.20108 .20133	4.97438 4.96690	.21925 .21956	4.56091 4.55458	.23762 .23793	4.20842	.25614 .25645	3.90417 3.89945	38
24	.18353	5.44857	.20164	4.95945	.21936	4.54826	.23823	4.19756	.25676	3.89474	36
25	.18384	5.43966	.20194	4.95201	.22017	4.54196	.23854	4.19215	.25707	3,89004	35
26	.18414	5.43077	.20224	4.94460	.22047	4.53568	.23885	4.18675	.25738	3.88536	34
27	.18444	5.42192	.20254	4.93721	.22078	4.52941	.23916	4.18137	.25769	3,88068	33
28	.18474	5.41309	.20285	4.92984	.22108	4.52316	.23946	4.17600	.25800	3.87601	32
29 30	.18504 .18534	5.40429 5.39552	.20315 .20345	4.92249 4.91516	.22139 .22169	4.51693 4.51071	.23977 .24008	4.17064 4.16530	.25831 .258 62	3.87136 3.86671	31 30
31	.18564	5.38677	.20376	4.90785	.22200	4.50451	.24039	4.15997	.25893	3.86208	29
32	.18594	5.37805	.20406	4.90056	.22231	4.49832	.24069	4.15465	.25924	3.85745	28
33	.18624	5.36936	.20436	4.89330	.22261	4.49215	.24100	4.14934	.25955 .25986	3.85284	27
34 35	.18654	5.36070 5.35206	.20466 .20497	4.88605 4.87882	.22292	4.48600	.24131 .24162	4.14405 4.13877	.26017	3.84824 3.84364	25
36	.18714	5,34345	.20527	4.87162	,22353	4.47374	,24193	4,13350	.26048	3.83906	24
37	.18745	5,33487	,20557	4.86444	.22383	4.46764	.24223	4.12825	.26079	3.83449	23
38	.18775	5.32631	.20588	4.85727	.22414	4.46155	.24254	4.12301	.26110	3.82992	22
39 40	.18805 .18835	5.31778 5.30928	.20618 .20648	4,85013 4,84300	.22444 .22475	4.45548	.24285 .24316	4.11778 4.11256	.26141 .26172	3.82537 3.82083	21
l							İ	'			1
41	.18865	5.30080	.20679	4.83590	.22505	4.44338	.24347	4.10736	.26208	3.81630	19
42 43	.18895 .18925	5.29235 5.28393	.20709 .20739	4.82882 4.82175	.22536 .22567	4.43735 4.43134	.24377 .24408	4.10216	.26235 .26266	3.81177 3.80726	18
44	.18955	5.27553	.20770	4.81471	.22597	4.42534	.24439	4.09182	.26297	3.80276	16
45	.18986	5.26715	.20800	4.80769	.22628	4.41936	.24470	4.08666	.26328	3.79827	15
46	.19016	5.25880	.20830	4.80068	.22658	4.41340	.24501	4.08152	.26359	3.79378	14
47	.19046	5.25048	.20861	4.79370	.22689	4.40745	.24532	4.07639	.26390	3.78931	13
48 49	.19076 .19106	5.24218	.20891 .20921	4.78673 4.77978	.22719 .22750	4.40152 4.39560	.24562 .24593	4.07127 4.06616	.26421 .26452	3.78485 3.78040	12
50	.19136	5.22566	.20952	4.77286	.22781	4,38969	.24624	4.06107	.26483	3.77595	10
51	.19166	5.21744	.20982	4.76595	,22811	4.38381	.24655	4.05599	.26515	3.77152	9
52	.19197	5.20925	.21013	4.75906	.22842	4.37793	.24686	4.05092	.26546	3.76709	8
53	.19227	5.20107	.21043	4.75219	.22872	4.37207	.24717	4.04586	.26577	3.76268	7
54	.19257	5.19293	.21073	4.74534	.22903	4.36623	.24747	4.04081	.26606	3.75828	5
55 56	.19287 .19317	5.18480 5.17671	.21104 .21134	4.73851 4.73170	.22984	4.36040 4.35459	.24778	4.03578	.26639 .26670	3.75388 3.74950	1
57	.19317	5.16863	.21164	4.72490	.22904	4.34879	.24840	4.02574	.26701	3.74512	3
58	,19378	5.16058	.21195	4.71813	.23026	4.34300	.24871	4.02074	.26733	3.74075	2
59	.19408	5.15256	.21225	4.71137	.23056	4.33723	.24902	4.01576	.26764	3.73640	1
60	.19438	5.14455	.21256	4.70463	.23087	4.33148	.24933	4.01078	.26795	3.73205	٥
	C-4	T	C		C-1	Tons	C-4	Tons	Cotor	Tana	-
١.	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	
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′	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	ľ
0	.20795	8.73205	.28675	3.48741	.30573	3.27085	.32492	3.07768	.34438	2.90421	64
1	.26826	8.72771	.28706	3.48359	.30605	3.26745	.32524	3.07464	.84465	2.90147	59
3	26857 .26888	3.72338	.28738	3.47977	.30637	3.26406	.32556	3.07160	.34498	2.89873	58
4	.26920	3.71907 3.71476	.287 69 .28800	3.47596 3.47216	.30669 .30700	3.26067 3.25729	.32588 .32621	3.06857	.84530	2.89600	5
5	.26951	3.71046	.28832	3.46837	.30732	3.25392	.82653	3.06554 3.06252	.34563 .34596	2.89327 2.89055	56
6	.26982	8.70616	.28864	3.46458	.80764	3.25055	.32685	3.05950	.34628	2.88783	5
7	.27018	3.70188	.28895	3.46080	.30796	3.24719	.32717	3.05649	.34661	2.88511	5:
8	.27044	8.69761	.28927	8.45703	.30828	3.24383	.82749	3.05349	.34698	2.88240	5:
9	.27076 .27107	3.69335 3.68909	.28958 .28990	3.45327 3.44951	.30860 .30891	3.24049 3.23714	.32782 .32814	3.05049 3.04749	.34726 .34758	2.87970 2.87700	51 50
1	.27138	3.68485	.29021	3.44576	.80923	3.23381	.32846	3.04450	.84791	2.87430	45
3	.27169 .27201	3.68061 3.67638	.29053 .29084	3.44202 3.43829	.30955 .30987	3.23048 3.22715	.32878 .32911	3.04152 3.03854	.34824	2.87161	48
4	.27232	3.67217	.29116	3.43456	.31019	3.22384	.32911	3.03556	.34856 .34889	2.86892 2.86624	47
5	.27263	3.66796	.29147	3.43084	.31051	3.22053	.32975	3.03260	,34922	2.86356	45
6	.27294	3.66376	.29179	3.42713	,81083	3.21722	.33007	3.02963	.34954	2.86089	44
7	.27326	8.65957	.29210	3.42343	.81115	3.21392	.33040	3.02667	.84987	2.85822	43
8	.27357 .27388	3.65538 3.65121	.29242 .29274	8.41973	.31147	3.21063	.83072	3.02372	.35020	2.85555	42
.0	.27419	8.64705	.29805	3.41604 3.41236	.31178 .31210	3.20734 3.20406	.33104 .38136	3.02077 3.01783	.85052 .35085	2.85289 2.85023	41
11	.27451	3.64289	.29337	3.40869	.81242	3.20079	.83169	3.01489	.35118	2.84758	39
3	.27482	3.63874	.29368	3.40502	.81274	8.19752	.33201	3.01196	.35150	2.84494	38
24	.27513 .27545	3.63461 3.63048	.29400 .29432	3.40136 3.39771	.31306 .31338	3.19426 3.19100	.33233 .33266	3.00903 3.00611	.35183 .35216	2.84229 2.83965	37
:5	.27576	3.62636	.29463	3.39406	.31370	3.18775	.33298	3.00319	.35248	2.83702	35
:6	.27607	8.62224	.29495	3.39042	.81402	3 18451	.33330	3,00028	.35281	2.83439	34
17	.27638	3.61814	.29526	3.38679	.31434	3.18127	.33363	2.99738	.35314	2.83176	33
18 19	.27670	3.61405	.29558 .29590	3.38317	.31466	3.17804	.33395	2.99447	.35346	2.82914	32
ñ	.27701 .27732	3.60996 3.60588	.29621	8.37955 8.37594	.31498 .31530	3.17481 3.17159	.33427 .33460	2.99158 2.98868	.85379 .85412	2.82653 2.82391	31 30
11	.27764	3.60181	.29653	3.37234	.31562	3.16838	.33492	2.98580	.85445	2.82130	29
13	.27795 .27826	3.59775 3.59370	.29685 .29716	3.36875 3.36516	.31594 .31626	3.16517 3.16197	.88524 .88557	2.98292 2.98004	.85477 .35510	2.81870 2.81610	28 27
ũ	.27858	3.58966	.29748	3.36158	.81658	3.15877	.33589	2.97717	.35548	2.81350	26
15	.27889	3.58562	29780	3.35800	.81690	3.15558	.33621	2.97430	.85576	2.81091	25
16	.27921	3.58160	.29811	8.85448	.81722	8.15240	.33654	2.97144	.35608	2.80833	24
17 18	.27952 .27963	3.57758 3.57357	. 19843 . 198 75	3.85087 3.84732	.81754	3.14922	.83686	2.96858	.35641	2.80574	23
19	.28015	8.56957	.29906	8.84977	.31786 .31818	3 14605 3.14288	.83718 .83751	2.96573 2.96288	.35674 .35707	2.80316 2.80059	22 21
10	.28046	3.56557	.29938	3.84023	.81850	8.13972	.83783	2.96004	.85740	2.79802	20
11	.28077 .28109	3.56159 3.55761	.29970 .30001	3.33670 3.33317	.31882 .31914	3.13656 3.13341	.33816 .33848	2.95721	.35772	2.79545	19
3	.28140	3,55364	.80033	3.32965	.81946	3,13027	,33881	2.95437 2.95155	.35805 .35838	2.79289 2.79033	18
14	.28172	8.54968	.30065	3.32614	.31978	3.12713	.33913	2.94872	.35871	2.78778	16
15	.28203	3.54578	30097	3.82264	.32010	3.12400	.33945	2.94591	.35904	2.78523	15
16	.28234	8.54179	.80128	3.31914	.32042	3.12087	.33978 .34010	2.94309	.35937	2.78269	14
18	.28266 .28297	3.53785 3.53393	.30160 .30192	3.31565 3.81216	.32074 .32106	3.11775 3.11464	,34043	2.94028 2.93748	.35969 .36002	2.78014 2.77761	13
١	.28329	3.53001	,30224	3.30868	.32139	3.11153	34075	2.93468	.36035	2.77507	ii
10	.28360	3.52609	.30255	3.30521	.32171	3.10842	.34108	2.93189	.36068	2.77254	10
i1	.28391 .28423	8.52219 3.51829	.80287 .30319	3.30174 3.29829	.32203 .32235	3,10532 3,10223	.84140 .34173	2.92910 2.92632	.36101 .36134	2.77002	9
i3	.28454	3.51441	.30319	3.29829	.32235	3.10223	.34173	2.92652	.36154	2.76750 2.76498	8
4	.28486	3.51058	.30382	3,29139	.32299	3.09606	.34238	2.92076	.36199	2.76247	6
15	.28517	8.50666	.30414	3.28795	.32331	3.09298	34270	2.91799	.36232	2.75996	5
i6	.28549	3.50279	,30446	3.28452	32363	3.08991	,34303	2.91523	.36265	2.75746	4
i7	.28580 .28612	3.49894 3.49509	.30478 .30509	3.28109	.32396	3.08685 3.08379	.34335	2.91246	.36298 .36331	2.75496	3
19	.28643	3.49509 3.49125	.30541	3.27767 3.27426	.32428	8.08379	.34368 .34400	2.90971 2.90696	.36331	2.75246 2.74997	1
ž0	.28675	3,48741	.80573	3.27085	.32492	3.07768	.34433	2,90421	.36397	2,74748	à
-	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	-
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	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotan	8
0	.86897	2.74748	.38886	2.60509	.40408	2.47509	.42447	2.35585	.44528	2.24604	
1	.86430	2.74499	.88420	2.60283	.40436	2.47802	.42482	2.35395	.44558	2.24428	
2 3	.36463 .36496	2.74251 2.74004	.88453 .88487	2.60057	.40470	2.47095	.42516	2.35205	.44593	2.24252	
4	.36529	2.78756	.38520	2.59831 2.59606	.40504 .40538	2.46888 2.46682	.42551 .42585	2.35015 2.34825	.44627 .44662	2.24077 2.23901	
5	.36562	2.73509	.38553	2.59381	.40572	2.46476	.42619	2.34636	.44697	2.23727	
6	.36595	2.73263	.88587	2.59156	.40606	2.46270	.42654	2.84447	.44732	2.23553	1
7	.36628	2.73017	.38620	2.58932	.40640	2.46065	.42688	2.84258	.44767	2.23378	1
8	.36661	2.72771	.38654	2.58708	.40674	2.45860	.42722	2.84069	.44802	2.23204	H
9 10	.36694 .36727	2.72526 2.72281	.38687 .38721	2.58484 2.58261	.40707 .40741	2.45655 2.45451	.42757 .42791	2.33881 2.33693	.44837 .44872	2.23030	
11	.36760	2.72036	.88754	2.58658	.40775	2.45246	.42826	2.33505	.44907	2.22683	
12	.36793	2.71792	.38787	2.57815	.40009	2.45048	.42860	2.33817	.44942	2.22510	1
18	.36826	2.71548	.38821	2.57593	.40643	2.44839	.42894	2.33180	.44977	2.22337	
14 15	.36859 .36892	2.71305 2.71062	.38854 .38888	2.57371	.40677	2.44636	.42929	2.32943	.45012	2.22164	
16	.36925	2.7062	.38921	2.57150 2.56928	.40911 .40945	2.44433 2.44230	.42963	2.32756	.45047 .45082	2.21992 2.21819	
17	.86958	2.70577	.38955	2.56707	.40910	2.44230	.43032	2.32570 2.32883	.45117	2.21647	
18	.36991	2.70335	.38988	2.56487	.41013	2.43825	.48067	2.32197	.45152	2.21475	
19	.87024	2.70094	.89022	2.56266	.41047	2.43623	.48101	2.32012	.45187	2.21304	.
20	.87057	2.69853	.89055	2.56046	.41061	2.48422	.43186	2.31826	.45222	2.21132	1
21 22	.37090 .37123	2.69612 2.69871	.89069 .89122	2.55827	.41115	2.43220	.48170	2.81641	.45257	2.20961	
23	.37157	2.69131	.39122	2.55608 2.55389	.41149 .41183	2.43019 2.42819	43205 .43230	2.31456 2.31271	.45292 .45327	2.20790 2.20619	
24	.37190	2.68892	.39190	2.55170	.41217	2.42618	.43274	2.31261	.45362	2.20019	
25	37228	2.68653	.39223	2.54952	.41251	2.42418	.43308	2.30902	.45397	2.20278	
26	.37256	2.68414	.39257	2.54734	.41285	2.42218	.43343	2.30718	.45432	2.20108	
27	.37289	2.68175	.39290	2.54516	41819	2.42019	.43378	2.30534	.45467	2.19938	1
28	.37322	2.67937	.39324	2.54299	.41353	2.41819	.43412	2.30351	.45502	2.19769	1
29 30	.37355 .37388	2.67700 2.67462	.39357 .39391	2.54082 2.58865	.41387 .41421	2.41620 2.41421	.43447 .43481	2.30167 2.29984	.45538 .45573	2.19599 2.19430	
31	.87423	2.67225	.39425	2.53648	.41458	2.41223	.43516	2.29801	.45608	2.19261	1
32	.37455	2.66989	.39458	2.53482	.41490	2.41025	.43550	2.29619	.45643	2.19092	
33	.37488	2.66752	.39492	2.53217	.41524	2.40627	.43585	2.29487	.45678	2.19923	
34	.37521	2.66516	.39526	2,53001	.41558	2.40629	.43620	2.29254	.45713	2.18755	1
35	.37554	2.66281	.39559	2.52786	.41592	2.40432	.43654	2.29073	.45748	2.18587	1
36	.37588	2.66046	.39593	2.52571	.41626	2.40235	.43689	2.28891	.45784	2.18419	1
37 38	.37621 .37654	2.65811 2.65576	.39626 .39660	2.52357	.41660	2.40038	.43724	2.28710	.45819	2.18251	
39	.37687	2.65342	.39694	2.52142 2.51929	.41 694 .41728	2.39841 2.39645	.43758	2.28528 2.28348	.45854 .45889	2.18084 2.17916	
iõ	.37720	2.65109	.39727	2.51715	.41763	2.39449	.43828	2.28167	.45924	2.17749	
61 62	.37754 .37787	2.64875	.39761	2.51502	.41797	2.39253	.43862	2.27987	.45960	2.17582	
13	.37820	2.64642 2.64410	.39795 .39829	2.51289 2.51076	.41831 .41865	2.39058 2.38863	.43897	2.27806 2.27626	.45995	2.17416	
4	.37853	2.64177	.39862	2.50864	41899	2.38668	.43966	2.27626	.46065	2.17249 2.17083	
5	.37887	2.63945	.39896	2.50652	.41988	2.38473	.44001	2.27267	.46101	2.16917	
6	.37920	2.63714	.39930	2,50440	.41968	2.38279	.44036	2.27088	.46136	2.16751	1
7	.37953	2.63488	.39963	2.50229	42002	2.38084	.44071	2.26909	.46171	1 2.16585	
8	.37986 .38020	2.63252	.39997	2.50018	.42036	2.37891	.44105	2.26780	.46206	2.16420	i.
50	.38020	2.63021 2.62791	.40031 .40065	2.49807 2.49597	.42070 .42105	2.37697 2.37504	.44140 .44175	2.26552 2.26874	.46242 .46277	2.16255 2.16090	
1	.38086	2.62561	.40098	2.49386	.42189	2.37811	.44210	2.26196	.46312	2.15925	
2	.38120	2.62332	.40132	2.49177	.42178	2.37118	.44244	2.26018	.46348	2.15760	1
3	.38153	2.62103	.40166	2.48967	.42207	2.36925	.44279	2.25840	.46383	2.15596	
5	.38186 .38220	2.61874 2.61646	.40200 .40234	2.48758 2.48549	.42242 .42276	2.36783 2.36541	.44814	2.25663 2.25486	.46418 .46454	2.15432 2.15268	1
6	.38253	2.61418	.40267	2,48340	42310	2.36849	,44384	2.25309	.46489	2.15268	-
7	.38286	2.61190	.40301	2.48132	42345	2.36158	.44418	2.25182	46525	2.14940	
8	.38320	2.60963	.40335	2.47924	.42379	2.35967	.44453	2,24956	.46560	2.14777	
9	.38353 .38386	2.60786 2.60509	.40369 .40403	2.47716 2.47509	.42413 .42447	2.35776 2.35585	.44488 .44528	2.24780 2.24604	.46595 .46631	2.14614 2.14451	
-	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	1-
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<i>,</i>	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	ļ <i>'</i>
0	.46631	2.14451 2.14288	.48778	2.05080	.50953 .50969	1.96361 1.96120	.53171	1.88073 1.87941	.55431 .55469	1.80405 1.80281	60 59
1 2	.46792	2.14125	.48845	2.04879 2.04728	.51026	1.95979	.53246	1.87809	.55507	1.80158	58
3	.46737	2.13963	.48881	2.04577	.51068	1.96838	.53283	1.87677	.55545	1.80084	57
4	.46772 .46806	2.13801 2.13639	.48917 .48953	2.04426 2.04276	.51099 .51184	1.95698 1.95557	.53320 .58358	1.87546 1.87415	.55583 .55621	1.79911 1.79788	56 55
6	.46843	2.18477	.48989	2.04276	.51178	1.95417	.53395	1.87283	.55659	1.79665	54
7	.46879	2.13316	.49026	2.03975	.51209	1.95277	.58482	1.87152	.55697	1.79542	54 53
8	.46914 .46950	2.13154	.49062 .49098	2.03825 2.03675	.51246 .51283	1.95137	.53470 .53507	1.87021 1.86891	.55736 .55774	1.79419 1.79296	52 51
10	.46985	2.12832	.49134	2.03526	.51319	1.94858	.53545	1.86760	.55812	1.79174	50
11	.47021	2.12671	.49170	2.03376	.51356	1.94718	.53582	1.86630	.55850	1.79051	49
12	.47056	2.12511	.49206	2.03227	.51398	1.94579	.53620	1.86499	.55888	1.78929	48
18 14	.47092 .47128	2.12350 2.12190	.49242 .49278	2.03078	.51430 .51467	1.94440 1.94301	.53657 .53694	1.86369	.55926 .55964	1.78807 1.78685	47
15	.47163	2.12030	.49315	2.02780	.51508	1.94162	,53732	1.86109	.56008	1.78563	45
16 17	.47199 .47234	2.11871	.49351 .49387	2.02631	.51540 .51577	1.94023 1.93885	.53769 .53807	1.85979	.56041 .56079	1.78441	44
18	.47270	2.11711	.49387	2.02385	.51614	1.93885	.53844	1.85850	.56117	1.78319	42
19	.47305	2.11392	.49459	2.02187	.51651	1.93608	.53882	1.85591	.56156	1.78077	41
20	.47341	2.11233	.49495	2.02069	.51688	1.93470	.53920	1.85462	.56194	1.77955	40
21 22	.47377	2.11075 2.10916	.49582 .49568	2.01891 2.01743	.51724 .51761	1.93332 1.93195	.53957 .53995	1.85883	.56232 .56270	1.77834	39 38
23	.47448	2.10758	.49604	2.01596	.51798	1.93057	.54082	1.85075	.56309	1.77592	37
24	.47483	2.10600	.49640	2.01449	.51835	1.92920	.54070	1.84946	.56347	1.77471	36
25 26	.47519 .47555	2.10442	.49677 .49713	2.01302 2.01155	.51872 .51909	1.92782	.54107 .54145	1.84818	.56885 .56424	1.77351 1.77230	35 34
27	.47590	2.10126	.49749	2.01008	.51946	1.92508	.54183	1.84561	.56462	1.77110	33
28	.47626	2.09969	.49786	2,00862	.51983	1.92371	.54220	1.84483	.56501	1.76990	32
29 30	.47662 .47698	2.09811 2.09654	.49822 .49858	3.00715 2.00569	.52020 .52057	1.92235 1.92098	.54258 .54296	1.84305 1.84177	.56539 .56577	1.76869 1.76749	31 30
31	.47788	2.09496	.49894	2.00423	.52094	1.91962	.54383	1.84049	.56616	1.76629	29
32	.47769	2.09841	.49981	2.00277	.52131	1.91836	.54871	1.83922	.56654	1.76510	28
33 34	.47805 .47840	2.09184 2.09028	.49987 .50004	2.00131 1.99986	.52168 .52205	1.91690 1.91554	.54409	1.83794	.56693 .56731	1.76390 1.76271	27 26
35	.47876	2.08872	.50040	1.99841	.52242	1.91418	.54484	1.83540	.56769	1.76151	25
36 37	.47912	2.08716	.50076	1.99695 1.99550	.52279	1.91282	.54522	1.83413	.56808	1.76032	24 23
38	.47948 .47984	2.06405	.50113 .50149	1.99406	.52816 .52853	1.91147 1.91012	.54560 .54597	1.83286	.56846 .56885	1.75913	23
39	.48019	2.08250	.50185	1.99261	.52390	1.90876	.54635	1.83033	.56923	1.75675	21
40	.48055	2.08094	.50222	1.99116	.52427	1.90741	.54673	1.82906	.56962	1.75556	20
41 42	.48091 .48127	2.07989	.50258 .50295	1.98972 1.98828	.52464 .52501	1.90607 1.90472	.54711 .54748	1.82780	.57000 .57089	1.75437 1.75319	19 18
43	.48163	2.07630	.50331	1.98684	.52588	1.90337	.54786	1.82528	.57078	1.75200	17
44 45	.48198 .48234	2.07476	.50868 .50404	1.98540 1.98396	.52575 .52613	1.90203	.54824 .54862	1.82402	.57116	1.75082	16 15
46	.48270	2.07167	.50441	1.98396	.52650	1.89935	.54900	1.82276	.57155 .57193	1.74964	14
47	.48306	2.07014	.50477	1.98110	.52687	1.89801	.54938	1.82025	.57232	1.74728	13
48 49	.48342	2.06860	.50514 .50550	1.97966	.52724	1.89667	.54975	1.81899	.57271	1.74610	12
50	.48414	2.06553	.50587	1.97823 1.97681	.52761 .52798	1.89533 1.89400	.55013 .55051	1.81774 1.81 649	.57309 .57848	1.74492 1.74875	10
51	.48450	2.06400	.50623	1.97588	.52836	1.89266	.55089	1.81524	.57386	1.74257	9
52 58	.48486 .48521	2.06247	.50660 .50696	1.97395	.52878 52910	1.89183	.55127 .55165	1.81399 1.81274	.57425 .57464	1.74140	8
54	.48557	2.05942	.50783	1.97111	.52947	1.88867	.55203	1.81150	.57503	1.73905	6
55	.48593	2.05790	.50769	1.96969	.52985	1.88734	.55241	1.81025	.57541	1.73788	5
5 6 57	.48629	2,05687	.50806 .50843	1.96827 1.96685	.58022 .58059	1.88602 1.88469	.55279 .55317	1.80901	.57580 .57619	1.78671 1.78555	4 3
58	.48701	2.05838	.50879	1.96544	.53096	1.88387	.55355	1.80653	.57657	1.73438	2
59 60	.48787 .48778	2.05182 2.05080	.50916 ,50953	1.96402 1.96261	.53134 .53171	1.88205 1.88078	.55393 .55431	1.80529 1.80405	.57696 .57785	1.73321 1.73205	0
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'	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.57785	1.73205	.60086	1.66428	.62487	1.60033	.64941	1.53986	.67451	1.48256	
1	.57774	1.73089	.60126	1.66318	.62527	1.59930	.64982	1.53888	.67493	1.48163	59
2	.57813	1.72973	.60165	1.66209	.62568	1.59826	.65024	1.53791	.67536	1.48070 1.47977 1.47885	58
3	.57851	1.72857	.60205	1.66099	.62608	1.59723	.65065	1.53693	.67578 .67620	1.47977	57
4	.57890	1.72741 1.72625	.60245 .60284	1.65990 1.65881	.62649 .62689	1.59620	.65106	1.53595	.67620	1.47885	56 55
5	.57929 .57968	1.72509	.60324	1.65772	.62730	1.59517 1.59414	.65148	1.53497 1.53400	.67663 .67705	1.47792	54
6	.58007	1.72393	.60364	1.65663	.62770	1.59311	.65189 .65231	1.53302	.67748	1.47 699 1.47 60 7	53
8	.58046	1.72278	.60403	1.65554	.62811	1.59208	.65272	1.53205	.67790	1.47514	52
9	.58085	1.72163	.60443	1.65445	.62852	1.59105	.65314	1.53107	.67832	1.47422	51
10	.58124	1.72047	.60483	1.65337	.62892	1.59002	.65855	1.53010	.67875	1.47330	50
11	.58162	1.71982	.60522	1.65228 1.65120	.62933	1.58900	.65397	1.52913	.67917	1.47238	49
12	.58201 .58240	1.71817	.60562	1.65120	.62973 .63014	1.58797	.65438	1.52816	.67960	1.47146	48
13	.58240	1.71702 1.71588	.60602 .60642	1.65011 1.64908	.63055	1.58695 1.58593	.65480 .65521	1.52719	.68002 .68045	1.47053	47
14	.58318	1.71473	.60681	1.64795	.63095	1.58490	.65563	1.52622 1.52525	.68088	1.46870	45
15 16	.58357	1.71358	.60721	1.64687	.63136	1.58388	.65604	1.52429	.68130	1.46778	14
17	.58396	1.71244	.60761	1.64687 1.64579	.63177	1.58286	.65646	1.52332	.68173	1.46686	43
is	.58435	1.71129	.60801	1.64471	.63217	1.58184	.65688	1.52235	.68215	1.46595	42
19	.58474	1.71015	.60841	1.64471 1.64363	.63258	1.58083	.65729	1.52139	.68258	1.46503	41
20	.58513	1.70901	.60881	1.64256	.63299	1.57981	.65771	1.52043	.68301	1.46411	40
21	.58552	1.70787	.60921	1.64148	.63340	1.57879	.65813	1.51946	.68343	1.46320	39
22	.58591	1.70673	.60960 .61000	1.64041 1.63934	.63380	1.57778	.65854	1.51850	.68386	1.46229	38
23	.58631	1.70560	.61000	1.63934	.63421	1.57676	.65896	1.51754	.68429	1.46137	37
24 25	.58670 .58709	1.70446 1.70332	.61040 .61080	1.63826 1.63719	.63462 .63503	1.57575	.65938 .65980	1.51658	.68471 .68514	1.46046 1.45955	36 35
26	.58748	1.70332	.61120	1.63619	.63544	1.57474	.66021	1.51562 1.51466	.68557	1.45864	34
27	.58787	1.70106	.61160	1.63505	.63584	1.57271	.66063	1.51870	.68600	1.45773	33
28	,58826	1.69992	61200	1.63612 1.63505 1.63398	.63625	1.57170	.66105	1.51275	.68642	1.45682	32
29	.58865	1.69879	.61240	1.63292	.63666	1.57069	.66147	1.51179	.68685	1.45592	31
30	.58905	1.69766	.61280	1.63185	.63707	1.56969	.66189	1.51084	.68728	1.45501	30
31	.58944	1.69653	.61320	1.63079	.63748	1.56868	.66230	1.50988	.68771	1.45410	29
32	.58983	1.69541	.61360	1.62972	.63789	1.56767	.66272	1.50893	.68814	1.45320	28
33	.59022	1.69428	.61400	1.62866	.63830	1.56667	.66314	1.50797	.68857	1.45229	27
34 35	.59061 .59101	1.69316 1.69203	.61440 .61480	1.62760 1.62654 1.62548 1.62442	.63871 .63912	1.56566 1.56466	.66356 .66398	1.50702 1.50607	.68900 .68942	1.45139 1.45049	26 25
36	.59149	1.69091	.61520	1.62548	.63953	1.56366	.66440.	1.50512	.68985	1.44958	24
37	.59179	1.68979	.61561	1.62442	.63994	1.56265	.66482	1.50417	69028	1.44868	23
38	.59218	1.68866	.61601	1.62336	.64035	1.56165	.66524	1.50322	,69071	1.44778	22
39 40	.59258 .59297	1.68754	.61641 .61681	1.62230 1.62125	.64076 .64117	1.56065 1.55966	.66566 .66608	1.50228 1.50133	.69114 .69157	1.44688 1.44598	21 20
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41	.59336 .59376	1.68531 1.68419	.61721 .61761	1.62019 1.61914	.64158 .64199	1.55866 1.55766	.66650 .66692	1.50038 1.49944	.69200 .69243	1.44508	19 18
43	.59415	1.68308	.61801	1.61808	.64240	1.55666	.66734	1.49849	.69245	1.44329	17
44	.59454	1.68196	.61842	1.61703	.64281	1.55567	.66776	1.49755	.69329	1.44239	16
45	.59494	1.68085	.61882	1.61598	.64322	1.55467	.66818	1.49661	.69372	1.44149	15
46	.59533	1.67974	.61922	1.61493	,64363	1.55467 1.55368	.66860	1.49566	.69416	1.44060	14
47	.59573	1.67863	.61962	1.61388	.64404	1.55269	.66902	1.49472	.69459	1.43970	13
48	.59612	1.67752	.62003	1.61283	.64446	1.55170	.66944	1.49378	.69502	1.43881	12
49 50	.59651 .59691	1.67641 1.67530	.62043 .62083	1.61179 1.61074	.64487 .64528	1.55071 1.54972	.66986 .67028	1.49284 1.49190	.69545 .69588	1.43792 1.43708	11 10
51	.59730	1.67419	.62124	1.60970	,64569	1.54873	.67071	1.49097	.69631	1.43614	,
52	.59770	1.67309	.62124	1.60865	.64610	1.54774	.67113	1.49003	.69675	1.43525	8
53	,59803	1.67198	.62204	1.60761	.64652	1.54675	.67155	1.48909	.69718	1.43436	۴I
54	.59849	1.67088	.62245	1.60657	.64693	1.54576	.67197	1.48816	.69761	1.43347	6
55	.59888	1.66978	.62285	1.60553	.64734	1.54478	.67239	1.48722	.69804	1,43258	5
56	.59928	1.66867	.62325	1.60449	.64775	1.54379	.67232	1.48629	.69847	1,43169	4
57	.59967	1.66757	.62366	1.60345	.64817	1.54281	.67324	1.48536	.69891	1,43080	3
58 59	.60007	1.66647	.62406	1.60241	.64858 .64899	1.54183	.67366	1.48442	.69934 .69977	1.42992	1
60	.60046 .60086	1.66538 1.66428	.62446 .62487	1.60137 1.60033	.64941	1.54085 1.53986	.67409 .67451	1.48349 1.48256	.70021	1.42903 1.42815	6
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	Tang	Cotang									
0	.70021	1.42815	.72654	1.37638	.75355	1.32704	.78129	1.27994	.80978	1.23490	
1	.70064	1.42726 1.42638	.72699 .72743	1.37554 1.37470	.75401 .75447	1.32624	.78175 .78222	1.27917	.81027 .81075	1.23416	1
3	.70151	1.42550	.72788	1.37386	.75492	1.32044	.78269	1.27764	.81123	1.23270	1
4	.70194	1.42462	.72832	1.37302	.75538	1.32384	.78316	1.27688	.81171	1.23196	1
5	.70238	1.42374	.72877	1.37218	.75584	1.32304	.78363	1.27611	.81220	1.23123	1.5
6	.70281	1.42286	.72921	1.37134	.75629	1.32224	.78410	1.27535	.81268	1.23050	1 6
7	.70325	1.42198	.72966	1.37050	.75675	1.32144	.78457	1.27458	.81316	1.22977	
8 j	.70368 .70412	1.42110	.73010 .73055	1.36967 1.36883	.75721	1.32064	.78504	1.27382	.81364	1.22904	1
ő	.70455	1.42022 1.41934	.78100	1.36800	.75767 .75812	1.31984 1.31904	.78551 .78598	1.27306 1.27230	.81413 .81461	1.22758	1
1 2	.70499 .70542	1.41847 1.41759	.73144 .73189	1.36716 1.36633	.75858 .75904	1.31825 1.31745	.78645 .78692	1.27153 1.27077	.81510 .81558	1.22685 1.22612	1
3	.70586	1.41672	.73234	1.36549	.75950	1.31666	.78739	1.27001	.81606	1.22539	1
4	.70629	1.41584	.73278	1.36466	.75996	1.31586	.78786	1.26925	.81655	1.22467	١.
5	.70673	1,41497	.73323	1.36383	.76042	1.31507	.78834	1.26849	.81703	1.22394	1
6	.70717	1.41409	.73368	1.36300	.76088	1.31427	.78881	1.26774	.81752	1.22321	1
8	.70760 .70804	1.41322 1.41235	.78413 .78457	1.36217 1.36134	.76134	1.31348	.78928 .78975	1.26698 1.26622	.81800 .81849	1.22249	
9	.70848	1.41148	.78502	1.36051	.76180 .76226	1.31269 1.31190	.79022	1.26546	.81898	1,22176	1
20	.70891	1.41061	.73547	1 35968	.76272	1.31110	.79070	1.26471	.81946	1.22031	1
21	.70935 .70979	1.40974 1.40887	.73592 .73637	1.35885 1.35802	.76318 .76364	1.31031 1.30952	.79117 .79164	1.26395 1.26319	.81995 .82044	1.21959 1.21886	
23	.71023	1.40800	.73681	1.35719	.76410	1.30873	.79212	1.26244	.82092	1.21814	П
24	.71066	1.40714	.73726	1,35637	.76456	1.30795	.79259	1.26169	.82141	1.21742	П
25	.71110	1.40627	.73771	1.35554	.76502	1.30716	.79306	1.26093	.82190	1.21670	1
26	.71154	1.40540	.73816	1.35472	.76548	1.30637	.79354	1.26018	.82238	1.21598	1
27 28	.71198 .71242	1.40454	.73861 .73906	1.35389 1.35307	.76594 .76640	1.30558 1.30480	.79401 .79449	1.25943 1.25867	.82287 .82336	1.21526 1.21454	
29	.71285	1.40281	.73951	1.35224	.76686	1.30401	.79496	1.25792	.82385	1.21382	1
30	.71329	1.40195	.73996	1.35142	.76733	1.30323	.79544	1.25717	.82434	1.21310	
31 32	.71878 .71417	1.40109 1.40022	.74041 .74086	1.35060 1.34978	.76779 .76825	1.30244 1.30166	.79591 .79639	1.25642 1.25567	.82483 .82531	1.21238 1.21166	
33	.71461	1.39936	.74181	1.34896	.76871	1.30087	.79686	1.25492	.82580	1.21094	1
34	.71505	1.39650	.74176	1.34814	.76918	1.30009	.79784	1.25417	.82629	1.21023	1
35	.71549	1.39764	.74221	1.34732	.76964	1.29931	.79781	1.25848	.82678	1.20951	1
36 37	.71593 .71637	1.39679 1.39593	.74267 .74312	1.34650 1.34568	.77010 .77057	1.29853 1.29775	.79829 .79877	1.25268	.82727 .82776	1.20879 1.20808	Ì
38	.71681	1,39507	.74357	1.34487	.77103	1.29696	.79924	1.25118	.82825	1.20736	Ĺ
39	.71725	1.39421	.74402	1.34405	.77149	1.29618	.79972	1.25044	.82874	1.20665	1
40	.71769	1,39336	.74447	1.34323	.77196	1.29541	.80020	1.24969	.82923	1.20593	1
41 42	.71813 .71857	1.39250 1.39165	.74492 .74588	1.34242 1.34160	.77242 .77289	1.29463 1.29385	.80067 .80115	1.24895 1.24820	.82972 .83022	1.20522 1.20451	
43	.71901	1,39079	.74583	1.34079	.77835	1.29307	.80163	1.24746	.83071	1.20379	
44	.71946	1.38994	.74628	1.33998	.77382	1.29229	.80211	1.24672	.83120	1,20308	1
45 46	.71990 .72034	1.38909 1.38824	.74674	1.33916	.77428	1.29152	.80258 .80306	1.24597	.83169 .83218	1.20237 1.20166	1
47	.72034	1.38824	.74719 .74764	1.33835 1.33754	.77475 .77521	1.29074	.80354	1.24525	.83218	1.20166	1
48	.72122	1.38653	.74810	1.33673	.77568	1.28919	.80402	1.24375	,83317	1.20024	1
49	.72167	1.38568	.74855	1.33592	.77615	1.28842	.80450	1.24301	.83366	1.19953	
50	.72211	1.38484	.74900	1.33511	.77661	1.28764	.80498	1.24227	.83415	1.19882	
51	.72255	1.38399	.74946	1.33430	.77708	1.28687	.80546 .80594	1.24158	.83465 .83514	1.19811	1
52 53	.72299 .72344	1.38314	.74991 .75037	1.33349	.77754 .77801	1.28610 1.28533	.80642	1.24079 1.24005	.83564	1.19669	1
54	.72388	1.38145	.75082	1.33187	.77848	1.28456	.80690	1.23931	.83613	1.19599	1
55	.72432	1.38060	.75128	1.33107	.77895	1.28379	.80738	1.23858	.83662	1.19528	1
56	.72477	1.37976	.75178	1.33026	.77941	1.28302	.80786	1.23784	.83712	1.19457	İ
57	.72521 .72565	1.37891	.75219 .75264	1.32946	.77988 .78035	1.28225	.80834 .80882	1.23710	.83761 .83811	1.19387	1
59	.72610	1.37807	.75264	1.32865	.78085	1.28148	.80882	1,23637 1,23563	,83860	1.19316	1
60	.72654	1.37638	.75355	1.32704	.78129	1.27994	.80930	1.23563	.83910	1.19175	
	Cotang	Tang									
1	i	<u>.</u>		'			l	'			

NATURAL TANGENTS AND COTANGENTS.

40	P	41	lo .	4:	2 0	4	30	4	40	
Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
.83910	1.19175	.86929	1.15087	,90040 ,90093	1.11061	.98252	1.07237	.96569 .96625	1.08563	50
.83960	1.19105	.8 698 0 .87031	1.14969 1.14902	.90146	1.10996 1,10981	.93306 .93360	1.07174	.96681	1.03433	
.84009 .84059	1.19035 1.18964	.87081 .87082	1.14802	.90199	1.10981	.98415	1.07112	.96738	1.08872	57
	1.18894	.87133	1.14767	.90251	1.10802	.93469	1.06987	.96794	1.03312	54
.84108 .84158	1.18824	.87184	1.14699	.90304	1.10787	.98524	1.06925	.96850	1.03252	55
.84208	1.18754	.87236	1.14632	.90357	1.10672	.93578	1.06862	.96907	1.03192	54
.84258	1.18684	.87287	1.14565	.90410	1.10607	.93633	1.06800	.96963	1.03132	53
.84307	1.18614	.87888	1.14498	.90463	1.10543	.93688	1.06738	.97020	1.03072	54
.84357	1.18544	.87389	1.14430	.90516	1.10478	.93742	1.06676	.97076	1.03012	51
.84407	1.18474	.87441	1.14363	.90569	1.10414	.93797	1.06613	.97138	1.02952	54
.84457	1.18404	.87492	1.14296	.90621	1.10349	.98852 .93906	1.06551	.97189 .97246	1.02892 1.02832	45
.84507	1.18334	.87543	1.14229	.90674	1.10285	.93906			1.02532	
.84556	1.18264	.87595	1.14162	.90727 .90781	1.10220 1.10156	.94016	1.06427	.97302 .97359	1.02713	4
.84606 .84656	1.18194 1.18125	.87 646 .87 69 8	1.14095 1.14028	.90781	1.10156	.94016	1.06363	.97416	1.02653	1
.84706	1.18125	.87698 .87749	1.13961	.90687	1.10091	.94125	1.06241	.97472	1.02593	4
.84756	1.17986	.87801	1.13961	.90940	1.0027	.94120	1.06179	.07529	1.02533	4
.84806	1.17916	.87852	1.13828	.90993	1.09899	.94235	1.06117	.97586	1.02474	4
.84856	1.17846	.87904	1.13761	.91046	1.09834	.94290	1.06056	.97643	1.02414	4
.84906	1.17777	.87955	1.13694	.91099	1.09770	.94345	1.05994	.97700	1.02355	4
.84956 .85006	1.17706 1.17 63 8	.88007 .88059	1.13627 1.18561	.91158 .91206	1.09706	.94400 .94455	1.05932 1.05870	.97756 .97813	1.02295 1.02236	34
.85057	1.17569			.91259	1.09578		1.05810	.97870	1.02176	3
.85107	1.17500	.88110 .88162	1.1 349 4 1.1 34 28	.91813	1.09514	.94510 .94565	1.05747	.97927	1.02117	3
.85157	1.17430	.88214	1.13361	.91366	1.09450	.94620	1.05685	97984 1.020		32
.85207	1.17361	.88265	1.13295	.91419	1.09386	.94676	1,05624	.98041	1.01998	3
.85257	1.17292	.88317	1.13228	.91473	1.09322	.94731	1.05562	.98098	1,01939	33
.85308	1.17228	.88369	1.13162	.91526	1.09258	.94786	1.05501	.98155	1.01879	3
.85358	1.17154	.88421	1.13096	,91580	1.09195	.94841	1.05439	.98213	1.01820	31
.85408	1.17085	.88473	1.13029	.91633	1.09181	.94896	1.05378	.98270	1.01761	30
.85458	1.17016	.88524	1.12963	.91687	1.09067	.94952	1.05817	.98327	1.01702	25
.85509	1.16947	.88576	1.12897	.91740	1.09003	.95007	1.05255	.98384	1.01642	25
.85559	1.16878	.88628	1.12831	.91794	1.08940	.95062	1.05194	.98441	1.01588	27
.85609	1.16809	.88680	1.12765	.91847	1.08876	.95118	1.05133	.98499	1.01524	20
.85660	1.16741	.88732	1.12699	.91901	1.08818	.95178	1.05072	.98556	1.01465	25
.85710	1.16672	.88784	1.12688	.91955 .92008	1.08749	.95229	1.05010	.98613	1.01406	34
.85761 .85811	1.16608	.888 36 .88888	1.12567 1.12501	.92062	1.08686 1.08622	.95284 .95340	1.04949	.98671	1.01847 1.01288	23
.85862	1.16535 1.16466	.88940	1.12435	.92116	1.08559	.95395	1.04827	.98728 .98786	1.01229	21
.85912	1.16898	.88992	1.12369	.92170	1.08496	.95451	1.04766	.98848	1.01170	20
.85963	1.16329	.89045	1.12803	.92224	1.08482	.95506	1.04705	.98901	1.01112	19
.86014	1.16261	.89097	1.12238	.92277	1.08369	.95562	1.04644	.98958	1.01053	18
.86064	1.16192	.89149	1.12172	.92831	1.06306	.95618	1.04583	.99016	1,00994	17
.86115 .86166	1.16124 1.16056	.89201 .89253	1.12106 1.12041	.92885 .92489	1.08243	.95678	1.04522	.99078	1.00935	16
.86216	1.15987	.89253 .89306	1.12041	.92489	1.08179	.95729 .95785	1.04461	.99131 .99189	1.00876	15
.86267	1.15919	.89358	1.11975	.92547	1.08053	.95841	1.04840	.99247	1.00759	13
.86318	1.15851	.89410	1.11844	.92601	1.07990	.95897	1.04279	.99804	1,00701	12
.86368	1.15788	.89463	1,11778	.92655	1.07927	.95952	1.04218	.99362	1.00642	ii
.86419	1.15715	.89515	1.11713	.92709	1.07864	.96008	1.04158	.99420	1.00583	10
.86470	1.15647	.89567	1.11648	.92763	1.07801	.96064	1.04097	.99478	1.00525	9
.86521	1.15579	.89620	1.11582	.92817	1.07738	.96120	1.04086	.99536	1.00467	8
.86572 .86623	1.15511	.89672	1.11517	.92872 .92926	1.07676	.96176	1.03976	.99594	1.00408	7
.86674	1.15448 1.15375	.89725 .89777	1.11452 1.11387	.92926 .92980	1.07613	.96232	1.03915	.99652 .99710	1.00300	5
.86725	1.15378	.89830	1.11387	.93084	1.07487	.96344	1.08794	.99768	1,00231	4
.86776	1.15240	.89883	1.11256	.93088	1.07425	.96400	1,08784	.99826	1.00175	3
.86827	1.15172	.89985	1.11191	.93143	1.07862	.96457	1.03674	.99884	1.00116	3
.86878	1.15104	.899 88	1.11126	.93197	1.07299	.96513	1.03618	.99942	1.00058	ī
.86929	1.15087	,90040	1.11061	.98252	1.07287	.96569	1.08553	1.00000	1.00000	ō
Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	,
49	90	4	30 	4'	70	4	60 60	4	50	

LOGARITHMIC TABLES.

For detailed directions as to the use of logarithms see page 22. To Find the Logarithmic Sine, Cosine, Tangent, or Cotangent of an Angle From

0° to 45°.—In the table Logarithms of Trigonometric Functions, find the number of degrees at the top of the page, and the number of minutes in the left-hand column headed ('); opposite the latter, and under the proper head, find the desired logarithmic sine, cosine, tangent, or cotangent.

To Find the Logarithmic Sine, Cosine, Tangent, or Cotangent of an Angle From 45° to 90°.—In the table Logarithms of Trigonometric Functions, find the number of degrees at the bottom of the page, and the number of minutes in the right-hand column headed ('); opposite the latter, and above the proper head, find the desired logarithmic sine, cosine, tangent, or cotangent.

To Find the Logarithmic Functions for an Angle Containing Degrees, Minutes, and Seconds.—Find the logarithm for the degrees and minutes in the manner given above, then from the column headed "d." take the number next below the logarithm thus found; under the heading "P.P.," find a column headed by this number, and find in this column the number opposite the given number of seconds; add it to the logarithm already found for the degrees and minutes. If the exact number of seconds is not given under "P. P.," the proper values may be found by interpolating between the values given. Since the differences in the column headed "d." represent differences corresponding to 60 minutes, the amount to be added after the logarithm of the degrees and minutes has been found may be obtained by multiplying the

difference by the number of seconds and dividing the result by 60.

The columns headed "Cpl. 8." and "Cpl. 7." on pages 492-494 can be used to find logarithms of angles including seconds less than 3° and greater than 86°.

tind logarithms of angles including seconds less than 3° and greater than 86°. Reduce the degrees, minutes, and seconds to seconds, and use the following formulas, substituting for Cpl. S. and Cpl. T. the values given in the table, and for S. and T., the difference between 10 and Cpl. S. and Cpl. T. as given. For angles less than 4° , log sin $\alpha=\log\alpha''+3$; log tang $\alpha=\log\alpha''+1$; log cotg $\alpha=Cpl.\log\alpha''+Cpl.$ T. = Cpl. log tang $\alpha=\log\alpha''=\log\alpha''+1$; log cotg $\alpha=Cpl.$ T. = Cpl. log cotg $\alpha=Cpl.$ T. For angles greater than 86°, log cos $\alpha=\log(90^0-\alpha)''+1$; log tang $\alpha=Cpl.$ The Cpl. log (90° $\alpha=0$)'' + Cpl. T. = Cpl. log cotg $\alpha=\log(90^0-\alpha)''+1$; log tang $\alpha=Cpl.$ The Cpl. log (90° $\alpha=0$)'' + Cpl. T. = Cpl. log cotg $\alpha=\log(90^0-\alpha)''+1$; log tang $\alpha=Cpl.$ S. = log cotg $\alpha=Cpl.$ T. = Cpl. log tang $\alpha=Cpl.$ T.

COMMON LOGARITHMS OF NUMBERS.

No.	Log.	No.	Log.	No.	Log.	No.	Log.	No.	Log.
0	— œ	20	80 103	40	60 206	60	77 815	80	90 309
1	00 000	21	32 222	41	61 278	61	78 533	81	90 849
2	30 103	22	34 242	42	62 325	62	79 239	82	91 381
3	47 712	23	36 173	43	63 347	63	79 934	83	91 908
4	60 206	24	38 021	44	64 345	64	80 618	84	92 428
5	69 897	25	39 794	45	65 321	65	81 291	85	92 942
6	77 815	26	41 497	46	66 276	66	81 954	86	93 450
7	84 510	27	43 136	47	67 210	67	82 607	87	93 952
8	90 309	28	44 716	48	68 124	68	83 251	88	94 448
9	95 424	29	46 240	49	69 020	69	83 885	89	94 939
10	00 000	30	47 712	50	69 897	70	84 510	90	95 424
11	04 139	31	49 136	51	70 757	71	85 126	91	95 904
12	07 918	32	50 515	52	71 600	72	85 733	92	96 379
13	11 394	33	51 851	53	72 428	73	86 332	93	96 848
14	14 613	34	53 148	54	73 239	74	86 923	94	97 313
15	17 609	35	54 407	55	74 036	75	87 506	95	97 772
16	20 412	36	55 630	56	74 819	76	88 081	96	98 227
17	23 045	37	56 820	57	75 587	77	88 649	97	98 677
18	25 527	38	57 978	58	76 343	78	89 209	98	99 123
19	27 875	39	59 106	59	77 085	79	89 763	99	99 564
20	30 103	40	60 206	60	77 815	80	90 309	100	00 000

								_						
N.	L	. 0	1	2	3	4	5	6	7	8	9		P. 1	Р.
100	00	000	043	087	130	173	217	260	303	346	389			
101		432	475	518	561	604	647	689	732	775	817	4	4; 4	3 42
102		860	903	945	988	*030	*072	*115	*157	*199	*242	1 4	.4 4	.3 4.2
103	01		326	368	410	452	494	536	578	620	662	2 8	.8 8	.6 8.4
104	_	703	745	787	828	870	912	953	995	*036	*078	3 13 4 17	.2 12	
105 106	υz	119 531	160 572	202 612	243 653	284 694	325 735	366 776	407 816	449 857	490 898	4 17 5 22		
107	ı	938	979	*019	*060	*100	*141	*181	*222	*262	*302	6 26	4 25	.8 25.2
108	03	342	383	423	463	503	543	583	623	663	703	7 30 8 35	8 30.	
109		743	782	822	862	902	941	981	*021	*060	*100	9 39	6 38	7 37.8
110	04	139	179	218	258	297	336	376	415	454	493			
111		532	571	610	650	689	727	766	805	844	883	1 . 4	H 4	0 39
112	١	922	961	999	*038	*077	*115	*154	*192	*231	*269	1 4	.1 4.	0 3.9
113	J ⁰⁵	308	346	385	423	461	500	538	576	614	652	2 8	2 8.	0 7.8
114 115	ما	690 070	729 108	767 145	805 183	843 221	881 258	918 296	956 333	994 371	*032 408	3 12 4 16		0 11.7 0 15.6
116	ľ۳	446	483	521	558	595	633	670	707	744	781	5 20		
117	ı	819	856	893	930	967	*004	*041	*078	*115	*151	6 24	6 24.	0 23.4
118	07	188	225	262	298	335	372	408	445	482	518	7 28. 8 32	7 28. 8 32.	0 27.3
119	<u> _</u>	555	591	628	664	700	737	773	809	846	882	9 36	9 36.	0 35.1
120	<u> </u> _	918	954	990	*027	*063	*099	*135	*171	*207	*243			
121	08	279	314	350	386	422	458	493	529	565	600	3	8 3	7 36
122		636	672	707	743	778	814	849	884	920	955	1 3	8 3.	7 3.6
123 124	09	991 342	*026 377	*061	*096 447	*132	*167	*202	*237 587	*272	*307 656	2 7.	6 7.	4 7.3
125	lo ₂	691	726	412 760	795	482 830	517 864	552 899	934	621 968	*003	3 11 4 15	2 14.	1 10.8 B 14.4
126	10		072	106	140	175	209	243	278	312	346	5 19	0 18.	5 18.0
127	-·	380	415	449	483	517	551	585	619	653	687	6 22. 7 26.	8 22. 6 25.	
128		721	755	789	823	857	890	924	958	992	*025	8 80.	4 29	6 28.8
129	11	059	093_	126	160	193	227	261	294	327	361	9 34.	2 33.	3 32.4
130	_	394	428	461	494	528	561	594	628	661	694	١.	5 84	
131	12	727	760	793	826	860	893	926	959	992	*024	3	3 9.	33
132 133	l12	057 385	090 418	123 450	156 483	189 516	222 548	254 581	287 613	320 646	352 678	1 3.		
134	ı	710	743	775	808	840	872	905	937	969	*001	2 7. 3 10		
135	13	033	066	098	130	162	194	226	258	290	322	4 14	0 13.	6 13.2
136	1	354	386	418	450	481	513	545	577	609	640	5 17 6 21		0 16.5 4 19.8
137		672	704	735	767	799	830	862	893	925	956	7 24		
138 139	۱,,	988 301	*019 333	*051 364	*082 395	*114 426	*145 457	*176 489	*208 520	*289 551	*270 582	8 28 9 31	0 27.	
140		613	644	675	706	737	768	799	829	860	891	9 31	.5 30.	8 29.7
141	-	922	953	983				·			-	3	2 3	11 30
141	15		259	290	*014 320	*045 351	*076 381	*106 412	*137 442	*168 473	*198 503	1 1 1		1 1
143	ľ	534	564	594	625	655	685	715	746	776	806	1 3		
144	1	836	866	897	927	957	987	*017	*047	*077	*107	3 9		9.0
145	16	137	167	197	227	256	286	316	346	376	406	4 12	8 12.4	12.0
146	ı	435	465	495	524	554	584	613	643	673	702	5 16. 6 19.	0 15.6 2 18.6	
147 148	1,,	732 026	761 056	791 085	820	850	879	909	938	967	997 289	7 22	4 21.7	21.0
148	۱۳′	319	348	377	114 406	143 435	173 464	202 493	231 522	260 551	580	8 25. 9 28	6 24.8 8 27.9	24.0
150	-	609	638	667	696	725	754	782	811	840	869	" "	0 -1	
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					_		_				
150	17 609	638	667	696	725	754	782	811	840	869	
151	898	926	955	984	*013	*041	*070	*099	*127	*156	29 28
152	18 184	213	241	270	298	327	355	384	412	441	1 2.9 2.8
153 154	469 752	498 780	526 808	554 837	583 865	611 893	639 921	667 949	696 977	724 *005	2 5.8 5.6
155	19 033	061	089	117	145	173	201	229	257	285	3 8.7 8.4 4 11.6 11.2
155 156 157	312	340	368	396	424	451	479	507	535	562	5 14.5 14.0
157	590	618	645	673	700	728	756	783	811	838	6 17.4 16.8 7 20.3 19.6
158 159	866 20 140	893 167	921 194	948 222	976 249	*003 276	*030 303	*058 330	*085 358	*112 385	8 23.2 22.4 9 26.1 25.2
160	412	439	466	493	520	548	575	602	629	656	0 00.0
161	683	710	737	763	790	817	844	871	898	925	27 26
162	952	978	*005	*032	*059	*085	*112	*139	*165	*192	1 2.7 2.6
163 164	21 219 484	245 511	272 537	299 564	325 590	352 617	378 643	405 669	431 696	458 722	2 5.4 5.2
165	748	775	801	827	854	880	906	932	958	985	3 8.1 7.8 4 10.8 10.4
166 167	22 011	037	063	089	115	141	167	194	220	246	5 13.5 13.0
167	272	298	324	350	376	401	427	453	479	505	6 16.2 15.6 7 18.9 18.2
168 169	531 789	557 814	583 840	608 866	634 891	660 917	686 943	712 968	737 994	763 *019	8 21.6 20.8 9 24.3 23.4
170	23 045	070	096	121	147	172	198	223	249	274	- 1 - 1 - 1 - 1 - 1 - 1
171	300	325	350	376	401	426	452	477	502	528	25
172	553	578 830	603	629	654	679	704	729	754	779	1 2.5
173 174	805 24 055	080	855 105	880 130	905 155	930 180	955 204	980 229	*005 254	*030 279	2 5.0 8 7.5
175	304	329	353	378	403	428	452	477	502	527	8 7.5 4 10,0
176	551	576	601	625	650	674	699	724	748	773	5 12.5
177	797	822	846	871	895	920	944	969	993	*018	6 15.0 7 17.5
178 179	25 042 285	066 310	091 334	115 358	139 382	164 406	188 431	212 455	237 479	261 503	8 20.0 9 22.5
180	527	551	575	600	624	648	672	696	720	744	0 , 22.0
181	768	792	816	840	864	888	912	935	959	983	24 23
182	26 007	031	055	079	102	126	150	174	198	221	1 2.4 2.3
183 184	245 482	269	293	316	340	364	387	411	435	458	2 4.8 4.6
185	717	505 741	529 764	553 788	576 811	600 834	623 858	647 881	670 905	694 928	3 7.2 6.9 4 9.6 9.2
186	951	975	998	*021	*045	*068	*091	*114	*138	*161	5 12.0 11.5
187	27 184	207	231	254	277	300	323	346	370	393	6 14.4 13.8 7 16.8 16.1
188	416	439	462	485	508	531	554	577	600	623	8 19.2 18.4
189	646 875	898	921	715 944	738 967	761 989	784 *012	807	830	852	9 21,6 20.7
190	28 103	126	149	171	194	217	240	*035 262	*058 285	*081 307	22 21
192	330	353	375	398	421	443	466	488	511	533	1 1
193	556	578	601	623	646	668	691	713	735	758	1 2.2 2.1 2 4.4 4.2
194	780	803	825	847	870	892	914	937	959	981	3 6.6 6.3
195	29 003 226	026	048	070	092	115	137	159	181	203	4 8.8 8.4 5 11.0 10.5
196 197	447	248 469	270 491	292 513	314 535	336 557	358 579	380 601	403 623	425 645	6 13.2 12.6
198	667	688	710	732	754	776	798	820	842	863	7 15.4 14.7 8 17.6 16.8
199	885	907	929	951	973	994	*016	*038	*060	*081	9 19.8 18.9
200	30 103	125	146	168	190	211	233	255	276	298	
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200	30 103	125	146	168	190	211	233	255	276	298	
201	320	341	363	384	406	428	449	471	492	514	22 21
202	535	557 771	578	600	621	643	664	685	707	728	1 2.2 2.1
203	750	771	792	814	835	856	878	899	920	942	2 4.4 4.2
204	963	984	*006	*027	*048	*069	*091	*112	*133	*154	3 6.6 6.3
205	31 175	197	218	239	260	281	302	323	345	366	4 8.8 8.4
206	387	408	429	450	471	492	513	534	555	576	5 11.0 10.5 6 13.2 12.6
207	597	618	639	660	681	702	723	744	765	785	7 15.4 14.7
208 209	806 32 015	827 035	848 056	869 077	890 098	911 118	931 139	952 160	973 181	994 201	8 17.8 16.8 9 19.8 18.9
210	222	243	263	284	305	325	346	366	387	408	1 8 18.0 10.9
211	428	449	469	490	510	531	552		593	-	20
212	634	654	675	695	715	736	756	572 777	797	613 818	1
213	838	858	879	899	919	940	960	980	*001	*021	1 2.0
214	33 041	062	082	102	122	143	163	183	203	224	2 4.0 3 6.0
214 215	244	264	284	304	325	345	365	385	405	425	4 8.0
216	445	465	486	506	526	546	566	586	606	626	5 10.0
217	646	666	686	706	726	746	766	786	806	826	6 12,0 7 14,0
218	846	866	885	905	925	945	965	985	*005	*025	7 14.0 8 16.0
219	34 044	064	084	104	124	143	163	183	203	223	9 18.0
220	242	262	282	301	321	341	361	380	400	420	
221	439	459	479	498	518	537	557	577	596	616	, 19
222	635	655	674	694	713	733	753	772	792	811	1 1.9
223	830	850	869	889	908	928	947	967	986	*005	2 3.8
224	35 025	044	064	083	102	122	141	160	180	199	8 5.7
225	218	238	257	276	295	315	334	353	372	392	4 7.6 5 9.5
226	411	430	449	468	488	507	526	545	564	583	6 11.4
227 228	603	622	641	660	679	698	717	736	755	774	7 13.3
229	793 984	813 *003	*021	851 *040	870 *059	889 *078	908 *097	927 *116	946 *135	965 *154	8 15.2 9 17.1
230	36 173	192	211	229	248	267	286	305	324	342	0 2
231	361	380	399	418	436	455	474	493	511	530	18
232	549	568	586	605	624	642	661	680	698	717	
233	736	754	773	791	810	829	847	866	884	903	1 1.8 2 3.6
234	922	940	959	977	996	*014	*033	*051	*070	*088	3 5.4
235 236	37 107	125	144	162	181	199	218	236	254	273	4 7.2
236	291	310	328	346	365	383	401	420	438	457	5 9.0
237	475	493	511	530	548	566	585	603	621	639	6 10.8 7 12.6
238	658	676	694	712	731	749	767	785	803	822	8 14.4
239	840	858	876	894	912	931	949	967	985	*003	9 16.2
240	38 021	039	057	075	093	112	130	148	166	184	
241	202	220	238	256	274	292	310	328	846	364	17
242	382	399	417	435	453	471	489	507	525	548	1 1.7
243 244	561 739	578 757	596 775	614 792	632 810	650 828	668	686 863	703	721 899	2 34
244	917	934	952	970	987	*005	846 *023	*041	881 *058	*076	3 5.1 4 6.8
246	39 094	111	129	146	164	182	199	217	235	252	5 8.5
247	270	287	305	322	340	358	375	393	410	428	6 10.2
248	445	463	480	498	515	533	550	568	585	602	7 11.9 8 13.6
249	620	637	655	672	690	707	724	742	759	777	9 15.3
250	794	,811	829	846	863	881	898	915	933	950	
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250	39 79	811	829	846	863	881	898	915	933	950	
251	96	985	*002	*019	*037	*054	*071	*088	*106	*123	. 18
252	40 140		175	192	209	226	243	261	278	295	1 1.8
253	31:	329	346	364 535	381	398	415	432	449	466	2 3.6
254	483 654	500 671	518 688	705	552 722	569 739	586 756	603 773	620 790	637 807	3 5.4 4 7.2
255 256	82		858	875	892	909	926	943	960	976	5 9.0
257	993	*010	*027	*044	*061	*078	*095	*111	*128	*145	6 10.8 7 12.6
258	41 16		196	212	229	246	263	280	296	313	8 14.4
259	330	-	363	380	397	414 581	597	614	464 631	481 647	9 16.2
260	49	-	531	547	564				797		17
261 262	66 83		697 863	714 880	731 896	747 913	764 929	780 946	963	814 979	1
263	99	*012	*029	*045	*062	*078	*095	*111	*127	*144	1 1.7 2 3.4
264	42 16	177	193	210	226	243	259	275	292	308	8 5.1
265	32	341	357	374	390	406	423	439	455	472	4 6.8 5 8.5
266 267	489 65		521 684	537 700	553 716	570 732	586 749	602 765	619 781	635 797	6 10.2
267 268	81		846	862	878	894	911	927	943	959	7 11.9 8 13.6
269	97		*008	*024	*010	*056	*072	*088	*104	*120	9 15.3
270	43 13	152	169	185	201	217	233	249	265	281	
271	29		329	345	361	377	393	409	425	441	16
272	45	473	489	505	521	537	553	569	584	600	1 1.6
273	616 775		648 807	664 823	680 838	696 854	712 870	727 886	743 902	759 917	2 8.2 8 4.8
274 275	93		965	981	996	*012	*028	*044	*059	*075	4 6.4
276	44 09		122	138	154	170	185	201	217	232	5 8.0
277	24		279	295	311	326	342	358	373	389	6 9.6 7 11.2
278	40- 56	420 576	436 592	451 607	467 623	483 638	498 654	514	529 685	545	8 12.8
279			747	762	778	793	809	824		700 855	9 14.4
280	710	-	902	917	932	948	963	979	840	*010	15
281 282	87: 45 02:	1 886 5 040	056	071	086	102	117	133	994 148	163	!
283	179		209	225	240	255	271	286	301	317	1 1.5 2 3.0
284	333	347	362	378	393	408	423	439	454	469	3 4.5
285	48		515	530	545	561	576	591	606	621	4 6.0 5 7.5
286 287	63° 789	652 8 803	667 818	682 834	697 849	712 864	728 879	743 894	758	773 924	6 9.0
288	93	954	969	984	*000	*015	*030	*045	909 *060	*075	7 10.5 8 12.0
289	46 09		120	135	150	165	180	195	210	225	9 13.5
290	240	255	270	285	300	315	330	345	359	374	
291	38 9		419	434	449	464	479	494	509	523	14
292	53	553	568	583	598	613	627	642	657	672	1 1.4
293 294	68′ 833	702 850	716 864	731 879	746 894	761 909	776 923	790 938	805. 953	820 967	2 2 8 3 4.2
295	98		*012	*026	*041	*056	*070	*085	*100	*114	4 5.6
296	47 129	144	159	173	188	202	217	232	246	261	5 7.0 6 8.4
297	270		305	319	334	349	363	378	392	407	7 9.8
298 299	42: 56		451 596	465 611	480 625	494 640	509 654	524 669	538 683	553 698	8 11.2 9 12.6
300	71:	-	741	756	770	784	799	813	828	842	
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N.	L. 0	1	2	3	4	5	6	7	8	9	P. P.
300	47 712	727	741	756	770	784	799	813	828	842	
301	857	871	885	900	914	929	943	958	972	986	
302	48 001		029	044	058	073	087	101	116	130	ĺ
303	144		173	187	202	216	230	244	259	273	
304	287		316	330	344	359	373	387	401	416	15
305	430		458	473	487	501	515	530	544	558	1
306 307	572 714		601 742	615 756	629 770	643 785	657 799	671 813	686 827	700 841	1 1.5 2 3.0
308	858		883	897	911	926	940	954	968	982	3 4.5
309	996		*024	*038	*052	*066	*080	*094	*108	*122	4 6.0 5 7.5
310	49 130	150	164	178	192	206	220	234	248	262	6 9.0 7 10.5
311	270	290	304	318	332	346	360	374	388	402	8 12.0
312	418	429	443	457	471	485	499	513	527	541	9 13.5
313	554	568	582	596	610	624	638	651	665	679	
314	693		721	734	748	762	776	790	803	817	
315	831		859	872	886	900	914	927	941	955	14
316	969		996	*010	*024	*037	*051	*065	*079	*092	
$\begin{array}{c} 317 \\ 318 \end{array}$	50 100 243	120 256	133 270	147 284	161 297	174 311	188 325	202 338	215 352	229 365	1 1.4 2 2.8
319	379	393	406	420	433	447	461	474	488	501	8 4.2
320	518	529	542	556	569	583	596	610	623	637	4 5.6 5 7.0 6 8.4
321	65		678	691	705	718	732	745	759	772	7 9.8
322	786	799	813	826	840	853	866	880	893	907	8 11.2 9 12.6
323	920	934	947	961	974	987	*001	*014	*028	*041	0 12.0
324	51 053		081	095	108	121	135	148	162	175	
325 326	188 325		215 348	228 362	242 375	255 388	268 402	282 415	295 428	308 441	
327	45	468	481	495	508	521	534	548	561	574	13
328	58		614	627	640	654	667	680	693	706	1 1.3
329	720		746	759	772	786	799	812	825	838	2 2.6 3 3.9
330	85	865	878	891	904	917	930	943	957	970	3 5.9 4 5.2 5 6.5
331	983		*009	*022	*035	*048	*061	*075	*088	*101	6 7.8
332	52 114		140	153	166	179	192	205	218	231	7 9.1 8 10.4
333 334	24		270	284	297	310	323 453	336	349	362	9 11.7
335	378 504		401 530	414 543	427 556	440 569	453 582	466 595	479 608	492 621	1
336	63		660	673	686	699	711	724	737	750	l
337	76		789	802	815	827	840	853	866	879	12
338	89:	905	917	930	943	956	969	982	994	*007	l ' ²
339	53 020	033	046	058	071	084	097	110	122	135	1 1.2 2 2.4 -
340	148	161	173	186	199	212	224	237	250	263	3 3.6 4 4.8
341	273		301	314	326	339	352	364	377	390	5 6.0
342	40		428	441	453	466	479	491	504	517	6 7.2 7 8.4
343	529 650		555	567 694	580 706	593 719	605 732	618	631 757	643 769	8 9.6
$\frac{344}{345}$	785		807	820	832	845	857	870	882	895	9 10.8
346	908		933	945	958	970	983	995	*008	*020	
347	54 03	045	058	070	083	095	108	120	133	145	l
348	158	170	183	195	208	220	233	245	258	270	ĺ
349	283		307	320	332	345	357	370	382	394	
350	40'	419	432	444	456	469	481	494	506	518	
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11.	12.0	1		3	7	ľ	0	'	0		1.1.
350	54 407	419	432	444	456	469	481	494	506	518	
351	531	543	555	568	580	593	605	617	630	642	
352 353	654	667 790	679 802	691 814	704 827	716 839	728 851	741 864	753 876	765 888	
354	777 900	913	925	937	949	962	974	986	998	*011	
355	55 023	035	047	060	072	084	096	108	121	133	13
356	145	157	169	182	194	206	218	230	242	255	1 1.3
357 358	267 388	279 400	291 413	303 425	315 437	328 449	340 461	352 473	364 485	376 497	2 2.6 3 3.9
359	509	522	534	546	558	570	582	594	606	618	4 5.2 5 6.5
360	630	642	654	666	678	691	703	715	727	739	6 7.8 7 9.1
361	751	763	775	787	799	811	823	835	847	859	8 10.4 9 11.7
362 363	871 991	883 *003	895 *015	907 *027	919 *038	931 *050	943 *062	955 *074	967 *086	979 *098	
364	56 110	122	134	146	158	170	182	194	205	217	I
365 366	229	241	253	265	277	289	301	312	324	336	12
366	348	360	372	384	396	407	419	431	443	455	l i
367 368	467 585	478 597	490 608	502 620	514 632	526 644	538 656	549 667	561 679	573 691	1 1.2 2 2.4
369	703	714	726	738	750	761	773	785	797	808	3 3.6 4 4.8
370	820	832	844	855	867	879	891	902	914	926	5 6.0 6 7.2
371	937	949	961	972	984	996	*008	*019	*031	*043	7 8.4 8 9.6
372 373	57 054 171	066 183	078 194	089 206	101 217	113	124	136 252	148 264	159 276	9 10.8
374	287	299	310	322	334	229 345	241 357	368	380	392	[
375	403	415	426	438	449	461	473	484	496	507	
376	519	530	542	553	565	576	588	600	611	623	11
377	634	646	657	669	680	692	703	715	726	738	1
378 379	749 864	761 875	772 887	784 898	795 910	807 921	818 933	830 944	841 955	852 967	1 1.1 2 2.2
380	978	990	*001	*013	*024	* 035	*047	*058	* 070	*081	3 3.3 4 4.4 5 5.5
381	58 092	104	115	127	138	149	161	172	184	195	6 6.6
382	206	218	229	240	252	263	274	286	297	309	7 7.7 8 8.8
383 384	320 433	331 444	343 456	354 467	365 478	377 490	388 501	399 512	410 524	422 535	9 9.9
385	546	557	569	580	591	602	614	625	636	647	
386	659	670	681	692	704	715	726	737	749	760	l
387	771	782	794	805	816	827	838	850	861	872	10
388 389	883 995	894 *006	906 *017	917 *028	928 *040	939 *051	950 *062	961 *073	973 *084	984 *095	1 1.0
390	59 106	118	129	140	151	162	173	184	195	207	2 2.0 3 3.0 4 4.0
391	218	229	240	251	262	273	284	295	306	318	5 5.0
392	329	340	351	362	373	384	395	406	417	428	6 6.0 7 7.0
393	439 550	450	461	472 583	483	494	506	517 627	528 638	539 649	8 8.0
i 394 i 395	660		572 682	693	594 704	605 715	616 726	737	748	759	9 9.0
396	770	780	791	802	813	824	835	846	857	868	l
397	879		901	912	923	934	945	956	966	977	l
398 399	988 60 097	999	*010 119	*021 130	*032 141	*043 152	*054 163	*065 173	*076 184	*086 195	
400	206	217	228	239	249	260	271	282	293	304	
N.	L. 0	1	2	3	4	5	6	7	8	9	P. P.

N.	L	0	1	2	3	4	5	6	7	8	9	P. P.
400	60 2	06	217	228	239	249	260	271	282	293	304	
401	3	14	325	336	347	358	369	379	390	401	412	ŀ
402	4	23	433	444	455	466	477	487	498	509	520	
403	5	31	541	552	563	574	584	595	606	617	627	i
404		38	649	660	670	681	692	703	713	724	735	l
405		46	756	767	778	788	799	810	821	831	842	i
406 407		53 59	863 970	874 981	885 991	895 *002	906 *013	917 *023	927 *034	938 *045	949 *055	11
408	61 ő		077	087	098	109	119	130	140	151	162	1 1.1
409		72	183	194	204	215	225	236	247	257	268	2 2.2
410	2	78	289	300	310	321	331	342	352	363	374	3 3.3 4 4.4 5 5.5
411	3	84	395	405	416	426	437	448	458	469	479	6 6.6
412		90	500	511	521	532	542	553	563	574	584	7 7.7 8 8.8
413		95	606	616	627	637	648	658	669	679	690	9 9.9
414 415		00 05	711 815	721 826	731 836	742 847	752 857	763 868	773 878	784 888	794 899	
416		09	920	930	941	951	962	972	982	993	*003	l
417		14	024	034	045	055	066	076	086	097	107	1
418	1	18	128	138	149	159	170	180	190	201	211	l
419	2	21	232	242	252	263	273	284	294	304	315	
420		25	335	346	356	366	377	387	397	408	418	10
421		28	439	449	459	469	480	490	500	511	521	
422 423	l b	31 34	542 644	552 655	562 665	572 675	583 685	593 696	603 706	613	624 726	1 1.0 2 2.0
424		37	747	757	767	778	788	798	808	716 818	829	3 3.0
425		39	849	859	870	880	890	900	910	921	931	4 4.0 5 5.0
426		41	951	961	972	982	992	*002	*012	*022	*033	6 6.0
427		43	053	063	073	083	094	104	114	124	134	
428 429		44 46	155 256	165 266	175 276	185 286	195 296	205 306	215 317	225 327	236 337	8 8.0 9 9.0
430		47	357	367	377	387	397	407	417	428	438	
431		48	458	468	478	488	498	508	518	528	538	
432		48	558	568	579	589	599	609	619	629	639	
433		49	659	669	679	689	699	709	719	729	739	
434	7	49	759	769	779	789	799	809	819	829	839	j
435		49	859	869	879	889	899	909	919	929	939	9
436 437	$\frac{9}{640}$	49	959 058	969	979	988 088	998	*008	*018	*028	*038	
438		48 47	157	068 167	078 177	187	098 197	108 207	118 217	128 227	137 237	1 0.9
439		46	256	266	276	286	296	306	316	326	335	2 1.8 3 2.7
440	3	45	355	365	375	385	395	404	414	424	434	4 3.6 5 4.5
441		44	454	464	473	483	493	503	513	523	532	6 5.4 7 6.3
442		42	552	562	572	582	591	601	611	621	631	8 7.2 9 8.1
443 444		$\frac{40}{38}$	650 748	660 758	670 768	680	689 787	699 797	709 807	719 816	729 826	
445		36	846	856	865	777 875	885	895	904	914	924	
446		33	943	953	963	972	982	992	*002	*011	*021	l
447	65 0	31	040	050	060	070	079	089	099	108	118	ļ
448		28 25	137 234	147	157 254	167	176	186	196	205	215	l
449 450		21	331	341	350	263 360	369	283 379	389	302	312 408	
N.	١.	0	1	2	3	4	5	6	7	8	9	P. P.

	N.	L. 0	1	2	3	4	5	6	7	8	9	P. P.
-	450	65 321	331	341	350	860	369	379	389	398	408	
l	451	418	427	437	447	456	466	475	485	495	504	ł
	452	514	523	533	543	552	562	571	581	591	600	
l	453	610	619	629	639	648	658	667	677	686	696	l
	454	706	715	725	734	744	753	763	772	782	792	ł
L	455	801	811	820	830	839	849	858	868	877	887	l
L	456	896	906	916	925	935	944	954	963	973	982	l 10
ı	457	992	*001	*011	*020	*030	*039	*049	*058	*068	*077	, ,
l	458	66 087	096	106	115	124	134	143	153	162	172	1 1.0
1	459	181	191	200	210	219	229	238	247	257	266	2 2.0 3 3.0
l	460	276	285	295	304	314	323	332	342	351	361	5 5.0 5 5.0
I	461	370	380	389	398	408	417	427	436	445	455	6 6.0
1	462	464	474	483	492	502	511	521	530	539	549	7 7.0 8 8.0
١	463	558	567	577	586	596	605	614	624	633	642	9 9.0
١	464	652	661	671	680	689	699	708	717	727	736	1
1	465	745	755	764	773	783	792	801	811	820	829	Ì
1	466	839	848	857	867	876	885	894	904	913	922	
- 1	467	932	941	950	960	969	978	987	997	*006	*015	
	468 469	67 025 117	034 127	043 136	052 145	062 154	071 164	080 173	089 182	099 191	108 201	
1	470	210	219	228	237	247	256	265	274	284	293	9
	471	302	311	321	330	339	348	357	367	376	385	
	472	394	403	413	422	431	440	449	459	468	477	1 0.9
	473	486	495	504	514	523	532	541	550	560	569	2 .1.8
	474	578	587	596	605	614	624	633	642	651	660	3 2.7 4 3.6
	475	669	679	688	697	706	715	724	733	742	752	5 4.5
	476	761	770	779	788	797	806	815	825	834	843	6 5.4
	477	852	861	870	879	888	897	906	916	925	934	7 6.8 8 7.2
	478	943	952	961	970	979	988	997	*006	*015	*024	8 7.2 9 8.1
	479	68 034	043	052	061	070	079	088	097	106	115	
	480	124	133	142	151	160	169	178	187	196	205	
	481	215	224	233	242	251	260	269	278	287	296	
	482	305	314	323	332	341	350	359	368	377	386	
	483 484	395 485	404	413 502	422 511	431	440	449	458	467	476	
	485	574	494 583	592	601	520 610	529 619	538 628	547 637	556 646	565 655	
	486	664	673	681	690	699	708	717	726	735	744	8
	487	753	762	771	780	789	797	806	815	824	833	
	488	842	851	860	869	878	886	895	904	913	922	1 0.8 2 1.6
	489	931	940	949	958	966	975	984	993	*002	*011	3 2.4 4 3.2
	490	69 020	028	037	046	055	064	073	082	090	099	5 4.0 6 4.8
	491	108	117	126	135	144	152	161	170	179	188	7 5.6
	492	197	205	214	223	232	241	249	258	267	276	8 6.4 9 7.2
	493	285	294	302	311	320	329	338	346	355	364	9 7.2
	494	373	381	390	399	408	417	425	434	443	452	
	495	461	469	478	487	496	504	513	522	531	539	
	496 497	548 636	557 644	566 653	574 662	583	592 679	601 688	609	618	627	
	497	723	732	740	749	671 758	767	775	697 784	705 793	714 801	
	499	810	819	827	836	845	854	862	871	880	888	
	500	897	906	914	923	932	940	949	958	966	975	
							<u> </u>					
	N.	L. 0	1	2	3	4	5	6	7	8	9	P. P.

N.	L	. 0	1	2	3	4	5	6	7	8	9	P. P.
500	69	897	906	914	923	932	940	949	958	966	975	
501	Г	984	992	*001	*010	*018	*027	*036	*044	*053	*062	Ī
502	170	070	079	088	096	105	114	122	131	140	148	1
503		157	165	174	183	191	200	209	217	226	234	į.
504	ŀ	243	252	260	269	278	286	295	303	312	321	
505		329	338	346	355	364	372	381	389	398	406	i
506		415	424	432	441	449	458	467	475	484	492	
507	ĺ	501	509	518	526	535	544	552	561	569	578	مار
508 509	l	586 672	595 680	603 689	612 697	621 706	629 714	638	646 731	655 740	663 749	1 0.9 2 1.8
510		757	766	774	783	791	800	808	817	825	834	3 2.7
511		842	851	859	868	876	885	893	902	910	919	5 4.5
512	l	927	935	944	952	961	969	978	986	995	*003	1 7 6.8
513	71	012	020	029	037	046	054	063	071	079	088	8 7.2 9 8.1
514	1	096	105	113	122	130	139	147	155	164	172	l • • • • · • · ·
515	l	181	189	198	206	214	223	231	240	248	257	l
516	ı	265	273	282	290	299	307	315	324	332	341	l
517	ı	349	357	366	374	383	391	399	408	416	425	l
518 519	1	433 517	441 525	450 533	458 542	466 550	475 559	483 567	492 575	500 584	508 592	l
520	_	600	609	617	625	634	642	650	659	667	675	
521		684	692	700	709	717	725	734	742	750	759	1 0.8
522	l	767	775	784	792	800	809	817	825	834	842	
523 524		850 933	858 941	867 950	875 958	883 966	892 975	900 983	908	917	925 *008	3 2.4
524 525	72		024	032	041	049	057	066	074	082	090	4 3.2 5 4.0
525 526	l'²	099	107	115	123	132	140	148	156	165	173	6 4.8
527	ĺ	181	189	198	206	214	222	230	239	247	255	7 5.6
528	1	263	272	280	288	296	304	313	321	329	337	8 6.4 9 7.2
529	_	346	354	362	370	378	387	395	403	411	419	-,
530	<u> </u> _	428	436	444	452	460	469	477	485	493	501	1
531	ı	509	518	526	534	542	550	558	567	575	583	l
532 533	ı	591	599	607	616	624	632	640	648	656	665	ł
533 534	1	673	681 762	689 770	697 779	705 787	713 795	722 803	730 811	738 819	746 827	!
535	1	754 835		852	860	868	876	884	892	900	908	l _
536	1	916	925	933	941	949	957	965	973	981	989	7
537	1	997	*006	*014	*022	*030	*038	*046	*054	*062	*070	1 0.7
538	73	078	086	094	102	111	119	127	135	143	151	2 1.4
53 9	L	159	167	175	183	191	199	207	215	223	231	3 2.1 4 2.8
540	L	239	247	255	263	272	280	288	296	304	312	5 3.5 6 4.2
541	1	320	328	336	344	352	360	368	376	384	392	7 4.9 8 5 6
542	ı	400	408	416	424	432	440	448	456	464	472	9 6.3
543	ł	480	488	496	504	512	520	528 608	536 616	544 624	552 632	1
544 545	1	560 640	568 648	576 656	584 664	592 672	600 679	687	695	703	711	1
546	1	719		735	743	751	759	767	775	783	791	i
547	1	799	807	815	823	830	838	846	854	862	870	l
548	l	878	886	894	902	910	918	926	933	941	949	l
549	<u> </u>	957	965	973	981	989	997	*005	*013	*020	*028	l
550	74	036	044	052	060	068	076	084	092	099	107	
N.	L	. 0	1	2	3	4	5	6	7	8	9	P. P.

N.	L. 0	1	2	3	4	5	6	7	8	9	P. P.
550	74 036	044	052	060	068	076	084	092	099	107	
551	115	123	131	139	147	155	162	170	178	186	
552	194	202	210	218	225	233	241	249	257	265	
553	273	280	288	296	304	312	320	327	335	343	
554	351	359	367	374	382	390	398	406	414	421	
555	429	437	445	453	461	468	476	484	492	500	
556	507	515	523	531	539	547	554	562	570	578	
557 558	586 663	593	601	609	617	624	632	640	648	656	
559	741	671 749	679 757	687 764	695 772	702 780	710 788	718 796	726 803	733 811	
560	819	827	834	842	850	858	865	873	881	889	
561	896	904	912	920	927	935	943	950	958	966	. 8
562	974	981	989	997	*005	*012	*020	*028	*035	*043	1 0.8
563	75 051	059	066	074	082	089	097	105	113	120	2 1.6 3 2.4
564	128	136	143	151	159	166	174	182	189	197	4 3.2
565	205	213	220	228	236	243	251	259	266	274	5 4.0
566	282 358	289	297	305	312	320	328	335	343	351	6 4.8 7 5.6
567 568	308 435	366 442	374 450	381 458	389 465	397 473	404 481	412 488	420 496	427 504	8 6.4
569	511	519	526	534	542	549	557	565	572	580 580	9 7.2
570	587	595	603	610	618	626	633	641	648	656	
571	664	671	679	686	694	702	709	717	724	732	
572	740	747	755	762	770	778	785	793	800	808	
573 574	815 891	823 899	831 906	838	846	853 929	861	868	876	884	
575	967	974	982	914 989	921 997	*005	937 *012	944 *020	952 *027	959 *035	
576	76 042	050	057	065	072	080	087	095	103	110	
577	118	125	133	140	148	155	163	170	178	185	
578	193	200	208	215	223	230	238	245	253	260	
579	268	275	283	290	298	305	313	320	328	335	
580	343	350	358	365	373	380	388	395	403	410	7
581	418	425	433	440	448	455	462	470	477	485	1 0.7
582	492	500	507	515	522	530	537	545	552	559	2 1.4
583	567	574	582	589	597	604	612	619	626	634	3 2.1
584	641	649	656	664	671	678	686	693	701	708	4 2.8 5 3.5
585 586	716 790	723 7 9 7	730	738 812	745	753 827	760	768	775	782	6 4.2
587	864	871	805 879	886	819	901	834 908	842 916	849 923	856 930	7 4.9
588	938	945	953	960	967	975	982	989	997	*004	8 5.6 9 6.3
589	77 012	019	026	034	041	048	056	063	070	078	0 0,0
590	085	093	100	107	115	122	129	137	144	151	
591	159	166	173	181	188	195	203	210	217	225	
592	232	240	247	254	262	269	276	283	291	298	
593	305	313	320	327	335	342	349	357	364	371	
594 505	379	386 450	393	401	408	415	422	430	437	444	
595 596	452 525	459 532	466 539	474 546	481 554	488 561	495 568	503 576	510 583	517 590	
597	597	605	612	619	627	634	641	648	656	663	
598	670	677	685	692	699	706	714	721	728	735	
599	743	750	757	764	772	779	786	793	801	808	
600	815	822	830	837	844	851	859	866	873	880	
N	L. 0	1	2	3	4	5	6	7	8	9	P. P.

N.	L. 0	1	2	3	4	5	6	7	8	9	P. P.
600	77 815	822	830	837	844	851	859	866	873	880	
601	887	895	902	909	916	924	931	938	945	952	
601 602 603 604	960	967	974	981	988	996	*003	*010	*017	*025	
603	78 032	039	046	053	061	068	075	082	089	097	
604	104	111	118	125	132	140	147	154	161	168	
605	176	183	190	197	204	211	219	226	233	240	
606 607	247	254	262	269	276	283	290	297	305	312	8
607	319	326	333	340	347	355	362	369	376	383	_
608	390	398	405	412	419	426	433	440	447	455	1 0.8 2 1.6
609	462	469	476	483	490	497	504	512	519 590	526 597	3 2.4 4 3.2
610	533	540	547	554	561	569	576	583	1		5 4.0
611	604	611	618	625 696	633 704	640	647 718	654 725	661 732	668 739	7 5.6
612 613	675 746	682 753	689 760	767	774	711 781	789	796	803	810	8 6,4
614	817	824	831	838	845	852	859	866	873	880	9 7.2
615	888	895	902	909	916	923	930	937	944	951	
616	958	965	972	979	986	993	*000	+007	*014	*021	
616 617	79 029	036	043	050	057	064	071	078	085	092	
618	099	106	113	120	127	134	141	148	155	162	
619	169	176	183	190	197	204	211	218	225	232	
620	239	246	253	260	267	274	281	288	295	302	7
621 622 623 624	309	316	323	330	337	344	351	358	365	372	1 0.7
622	379	386	393	400	407	414	421	428	435	442	2 1.4
623	449	456	463 532	470 539	477 546	484 553	491 560	498 567	505 574	511 581	3 2.1
625	518 588	525 595	602	609	616	623	630	637	644	650	4 2.8 5 3.5
626	657	664	671	678	685	692	699	706	713	720	6 4.2
627	727	734	741	748	754	761	768	775	782	789	7 4.9
627 628	796	803	810	817	824	831	837	844	851	858	8 5.6 9 6.3
629	865	872	879	886	893	900	906	913	920	927	9 6.3
630	934	941	948	955	962	969	975	982	989	996	
631	80 003	010	017	024	030	037	044	051	058	065	1
631 632	072	079	085	092	099	106	113	120	127	134	
633	140	147	154	161	168	175	182	188	195	202	
634	209	216	223	229	236	243	250	257	264	271	
634 635 636	277	284	291	298	305	312	318	325 393	332 400	339 407	6
636 637	346	353 421	359 428	366 434	373 441	380 448	387 455	462	468	475	
638	414 482	489	426	502	509	516	523	530	536	543	1 0,6 2 1,2
639	550	557	564	570	577	584	591	598	604	611	3 1.8 4 2.4
640	618	625	632	638	645	652	659	665	672	679	5 3.0
641	686	693	699	706	713	720	726	733	740	747	7 4.2
642	754	760	767	774	781	787	794	801	808	814	8 4.8 9 5.4
643	821	828	835	841	848	855	862	868	875	882	J 0.7
644	889	895	902	909	916	922	929	936	943	949	
645	956	963	969	976 043	983 050	990 057	996 064	*003 070	*010 077	*017 084	
646 647	81 023 090	030 097	037 104	111	117	124	131	137	144	151	
648	158	164	171	178	184	191	198	204	211	218	
649	224	231	238	245	251	258	265	271	278	285	
650	291	298	305	311	318	325	331	338	345	351	
N.	L. 0	1	2	3	4	5	6	7	8	9	P. P.

-	N.	L. 0	1	2	3	4	5	6	7	8	9	P. P.
€	350	81 291	298	305	311	318	325	331	338	345	351	
	651	358	365	371	378	385	391	398	405	411	418	1
	652	425		438	445	451	458	465	471	478	485	
	653	491		505	511	518	525	531	538	544	551	1
	654	558	564	571	578	584	591	598	604	611	617	ł
	655	624		637	644	651	657	664	671	677	684	I
l	655 656 657	690 757		704	710 776	717 783	723 790	730 796	737 803	743 809	750 816	1 .
l	658	823	829	836	842	849	856	862	869	875	882	ſ
	659	889		902	908	915	921	928	935	941	948	j
1	660	954	961	968	974	981	987	994	*000	*007	*014	,
١	661	82 020	027	033	040	046	053	060	066	073	079	1 0.7
1	662 663	086 151	092 158	099 164	105 171	112 178	119	125	132 197	138 204	145	2 1.4
1	664	217	223	230	236	243	184 249	191 256	263	269	210 276	8 2.1
1	665	282	289	295	302	308	815	321	328	334	341	4 2.8 5 3.5
1	666	347	354	360	367	373	380	387	393	400	406	6 4.2
ì	667	413	419	426	432	439	445	452	458	465	471	7 4.9 8 5.6
1	668	478	484	491	497	504	510	517	523	530	536	9 6.8
	669	543	549	556	562	569	575	582	588	595	601	
	670	607	614	620	627	633	640	646	653	659	666	
	671	672	679	685	692	698	705	711	718	724	730	İ
	672	737	743	750	756	763	769	776	782	789	795	
	673 674	802 866	808 872	814 879	821 885	827 892	834 898	840 905	847 911	853 918	860 924	
	675	930	937	943	950	956	963	969	975	982	988	
	676	995	*001	*008	*014	*020	+027	*033	*040	*046	*052	
	677	83 059	065	072	078	085	091	097	104	110	117	•
	678	123	129	136	142	149	155	161	168	174	181	l
	679	187	193	200	206	213	219	225	232	238	245	
	680 681	251	257 321	327	270	276 340	283	289 353	359	302	308	. 6
	682	315 378	385	391	334 398	404	347 410	417	423	429	436	1 0.6 2 1.2
	683	442	448	456	461	467	474	480	487	493	499	2 1.2 3 1.8
	684	506	512	518	525	531	537	544	550	556	563	4 2.4
	685	569	575	582	588	594	601	607	613	620	626	5 3.0 6 3.6
	686	632	639	645	651	658	664	670	677	683	689	7 4.2
	687 688	696 759	702 765	708 771	715 778	721 784	727 790	734	740 803	746 809	753 816	8 4.8 9 5.4
	689	822	828	835	841	847	853	860	866	872	879	7,5.4
	690	885	891	897	904	910	916	923	929	935	942	
	691	948	954	960	967	973	979	985	992	998	*004	
	692	84 011	017	023	029	036	042	048	055	061	067	
	693 694	073 136	080 142	086 148	092 155	098	105	111	117 180	123 186	130 192	
	695	198	205	211	217	161 223	167 230	173 236	242	248	255	
	696	261	267	273	280	286	292	298	305	311	317	
	697	323	330	336	342	348	354	361	367	373	379	
	698	386	392	398	404	410	417	423	429	435	442	
	699	448	454	460	466	473	479	485	491	497	504	
	700	510	516	522	528	535	541	547	553	559	566	
	N.	L. 0	1	2	3	4	5	6	7	8	9	P. P.

N.	L. 0	1	2	3	4	5	6	7	8	9	P. P.
700	84 510	516	522	528	535	541	547	553	559	566	
701 702	572	578	584	590	597	603	609	615	621	628	
702	634	640	646	652	658	665	671	677	683	689	
703	696	702	708	714	720	726	733 794	739	745	751	
704 705	757 819	763 825	770 831	776 837	782 844	788 850	856	800 862	807	813	
706	880	887	893	899	905	911	917	924	868 930	874 936	
707	942	948	954	960	967	973	979	985	991	997	7
708	85 003	009	016	022	028	034	040	046	052	058	1 0.7
709	065	071	077	083	089	095	101	107	114	120	2 1.4 3 2.1
710	126	132	138	144	150	156	163	169	175	181	3 2.1 4 2.8 5 3.5
711	187	193	199	205	211	217	224	230	236	242	6 4.2
712 713	248 309	254 315	260 321	266 327	272 333	278 339	285	291 352	297 358	303	7 4.9 8 5.6
714	309 370		382	388	394	400	345 406	352 412	418	364 425	9 6.3
715	431	437	443	449	455	461	467	473	479	485	
714 715 716	491	497	503	509	516	522	528	534	540	546	
717	552	558	564	570	576	582	588	594	600	606	
718	612	618	625	631	637	643	649	655	661	667	
719	673	679	685	691	697	703	709	715	721	727	
720	733	739	745	751	757	763	769	775	781	788	6
721 722 723	794	800	806	812	818	824	830	836	842	848	1
722	854	860	866	872	878	884	890	896	902	908	1 0.6 2 1.2
723 724	914 974	920 980	926 986	932 992	938 998	944 *004	950 *010	956 *016	962 *022	968 *028	3 1.8
725	86 034	040	046	052	058	064	070	076	082	088	4 2.4 5 3.0
726	094	100	106	112	118	124	130	136	141	147	6 3.6
727 728	153	159	165	171	177	183	189	195	201	207	7 4.2
728	213	219	225	231	237	243	249	255	261	267	8 4.8 9 5.4
729	273	279	285	291	297	303	308	314	320	326	(
730	332	338	314	350	356	362	368	374	380	386	
731	392 451	398	404	410	415	421	427	433 493	439	445)
732 733	510	457 516	463 522	469 528	475 534	481 540	487 546	493 552	499 558	504 564	
734	570	576	581	587	593	599	605	611	617	623	
734 735 736	629	635	641	646	652	658	664	670	676	682	
736	688	694	700	705	711	717	723	729	735	741	5 (
737	747	753	759	764	770	776	782	788	794	800	1 0.5
738	806 864	812	817	823	829	835	841	847	853	859	2 1.0
739 740	923	870 929	935	941	947	894 953	900	906	911	917 976	3 1.5 4 2.0 5 2.5
741	982	988	994	999	*005	*011	*017	*023	*029	*035	6 3.0
741	87 040	046	052	058	064	070	075	081	087	093	8 4.0
743	099	105	111	116	122	128	134	140	146	151	9 45
744 745	157	163	169	175	181	186	192	198	204	210	
745	216	221	227	233	239	245	251	256	262	268	j
746	$\frac{274}{332}$	280	286	291	297	303	309	315	320	326 384	
747 748	332 390	338 396	344 402	349 408	355 413	361 419	367 425	373 431	379 437	384 442	ŀ
749	448	454	460	466	471	477	483	489	495	500	
750	506	512	518	523	529	535	541	547	552	558	
N.	L. 0	1	2	3	4	5	6	7	8	9	P. P.

	И.	L. 0	1	2	3	4	5	6	7	8	9	P. P.
-	750	87 506	512	518	523	529	535	541	547	552	558	
	751	564	570	576	581	587	593	599	604	610	616	
		622	628	633	639	645	651	656	662	668	674	
	752 758 754 755 756 757	679	685	691	697	703	708	714	720	726	731	
	755	737 795	743 800	749 806	754 812	760 818	766 823	772 829	777 835	783 841	789 846	
l	756	852	858	864	869	875	881	887	892	898	904	
l	757	910	915	921	927	933	938	944	950	955	961	
١	758 759	967 88 024	973 030	978 036	984 041	990 047	996 053	*001 058	*007 064	*013 070	*018 076	
١	760	081	087	093	098	104	110	116	121	127	133	8
١	761	138	144	150	156	161	167	173	178	184	190	1 0.6
1	762 763	195 252	201 258	207 264	213 270	218 275	224 281	230 287	235 292	241 298	247 304	2 1.2
	764	309	315	321	326	332	338	343	349	355	360	3 1.8 4 2.4
	765	366	372	377	383	389	395	400	406	412	417	5 3.0
	766 767	423	429	434	440	446	451	457	463	468	474	6 3.6 7 4.2
	767	480 536	485 542	491 547	497 553	502 559	508 564	513 570	519 576	525 581	530 587	8 4.8
	769	593	598	604	610	615	621	627	632	638	643	9 5.4
	770	649	655	660	666	672	677	683	689	694	700	
	771	705	711	717	722 779	728	734	739	745	750	756	
	772 773	762 818	767 824	773 829	779 835	784 840	790 846	795 852	801 857	807 863	812 868	
	774	874	880	885	891	897	902	908	913	919	925	
	775	930	936	941	947	953	958	964	969	975	981	
	776	986	992	997	*003	*009	*014	*020	*025	*031	*037	
	777	89 042 098	048 104	053 109	059	064	070	076	081	087	092	
	778 779	154	159	165	115 170	120 176	126 182	131 187	137 193	143 198	148 204	
	780	209	215	221	226	232	237	243	248	254	260	5
	781	265	271	276	282	287	293	298	304	310	315	1 0.5
	782	321	326	332	337	343	348	354	360	365	371	2 1.0
	783 784	376 432	382 437	387 443	393 448	398 454	404 459	409 465	415 470	421 476	426 481	3 1.5 4 2.0
	785	487	492	498	504	509	515	520	526	531	537	5 2.5
	786	542	548	553	559	564	570	575	581	586	592	6 3.0 7 3.5
	787 788	597 653	603 658	664	614	620	625 680	631 686	636	642 697	647 702	8 4.0
	789	708	713	719	669 724	675 730	735	741	746	752	757	9 4.5
	790	763	768	774	779	785	790	796	801	807	812	
	791	818	823	829	834	840	845	851	856	862	867	
	792 793	873 927	878 933	883 938	889 944	894 949	900 955	905 960	911 966	916 971	922 977	
	794	982	988	993	998	*004	*009	*015	*020	*026	*031	
	795	90 037	042	048	053	059	064	069	075	080	086	
	796	091	097	102	108	113	119	124	129	135	140	
	797 798	146 200	151 206	157 211	162 217	168 222	$\frac{173}{227}$	179 233	184 238	189 244	195 249	
	799	255	260	266	271	276	282	287	293	298	304	
	800	309	314	320	325	331	336	342	347	352	358	
	N.	L. 0	1	2	3	4	5	6	7	8	9	P. P.

N.	L. 0	1	2	3	4	5	6	7	8	9	P. P.
800	90 309	314	320	325	331	336	342	347	352	358	
801	363	369	374	380	385	390	396	401	407	412	
802	417	423	428	434	439	445	450	455	461	466	
803	472	477	482	488	493	499	504	509	515	520	
804	526	531	536	542	547	553 607	558	563	569	574	
805 806	580 634	585 639	590 644	596	601	607	612	617	623 677	628	
807	687	693	698	650 703	655 709	660 714	666 720	671 725	730	682 736	
808	741	747	752	757	763	768	773	779	784	789	
809	795	800	806	811	816	822	827	832	838	843	
810	849	854	859	865	870	875	881	886	891	897	
811	902	907	913	918	924	929	934	940	945	950	6
812	956	961	966	972	977	982	988	993	998	*004	1 0.6
813	91 009	014	020	025	030	036	041	046	052	057	2 1.2 3 1.8
814	062	068	073	078	084	089	094	100	105	110	4 2.4
815	116	121 174	126	132	137	142	148	153	158	164	5 3.0
816 817	169 222	228	180 233	185 238	190 243	196 249	201 254	206 259	212 265	217 270	6 3.6 7 4.2
818	275	281	286	291	297	302	307	312	318	323	8 4.8
819	328	334	839	344	350	355	360	365	871	376	9 5.4
B20	381	387	392	397	403	408	413	418	424	429	
821	434	440	445	450	455	461	466	471	477	482	
822	487	492	498	503	.508	514	519	524	529	535	
823 824	540 593	545 598	551 603	556	561	566	572	577	582	587	
825	645	651	656	609 661	614 666	619 672	624 677	630 682	635 687	640 698	
826	698	703	709	714	719	724	730	735	740	745	
827	751	756	761	766	772	777	782	787	793	798	
828	803	808	814	819	824	829	834	840	845	850	
829	855	861	866	871	876	882	887	892	897	903	
330	908	913	918	924	929	934	939	944	950	955	5
831	960	965	971	976	981	986	991	997	*002	*007	1 0.5
832	92 012	018	023	028	033	038	044	049	054	059	2 1.0
833	065	070	075	080	085	091	096	101	106	111	3 1.5
834 835	117 169	$\frac{122}{174}$	127 179	132 184	137 189	143 195	148 200	153 205	158 210	163 215	4 2.0 5 2.5
836	221	226	231	236	241	247	252	257	262	267	6 3.0
837	273	278	283	288	293	298	304	309	314	319	7 3.5 8 4.0
838	324	3 3 0	335	340	345	350	355	361	366	371	9 4.5
839	376	381	387	392	397	402	407	412	418	423	·
340	428	433	438	443	449	454	459	464	469	474	
841	480	485	490	495	500	505	511	516	521	526	
842	531	536	542 593	547	552	557	562	567	572	578	
843 844	583 634	588 639	645	598 650	603 655	609 660	614	619 670	624 675	629 681	
845	586	691	696	701	706	711	716	722	727	732	
846	737	742	747	752	758	763	768	773	778	783	
847	788	793	799	804	809	814	819	824	829	834	
848	840	845	850	855	860	865	870	875	881	886	
849	891	896	901	906	911	916	921	927	932	937	
150	942	947	952	957	962	967	973	978	983	988	
N.	L. 0	1	2	3	4	5	6	7	8	9	P. P.

N.	L. 0	1	2	3	4	5	6	7	8	9	P. P.
850	92 942	947	952	957	962	967	973	978	983	988	
851	993	998	*003	*008	*013	*018	*024	*029	*034	*039	
852	93 044	049	054	059	064	069	075	080	085	090	
853	095	100 151	105 156	110 161	115 166	120 171	125 176	131 181.	136 186	141 192	
854 855	146 197	202	207	212	217	222	227	232	237	242	
856	247	252	258	263	268	273	278	283	288	293	6
857	298	303	308	313	318	323	328	334	339	344	1
858	349	354	359	364 414	369 420	374 425	379 430	384 435	389 440	394 445	1 0.6 2 1.2
859 860	399 450	404	409	465	470	475	480	485	490	495	3 1.8 4 2.4
			510	515	520	526	531	536	541	546	5 3.0 6 3.6
861 862	500 551	505 556	561	566	571	576	581	586	591	596	7 4.2
863	601	606	611	616	621	626	631	636	641	646	8 4.8 9 5.4
864	651	656	661	666	671	676	682	687	692	697	
865	702	707	712	717	722	727	732	737	742	747	
866	752	757 807	762 812	767 817	772 822	777 827	782 832	787 837	792 842	797 847	
867 868	802 852	857	862	867	872	877	882	887	892	897	
869	902	907	912	917	922	927	932	937	942	947	
870	952	957	962	967	972	977	982	987	992	997	5
871	94 002	007	012	017	022	027	032	037	042	047	1 0.5
872	052	057 106	062 111	067 116	072 121	077 126	082 131	086 136	091 141	096 146	2 1.0
873 874	101 151	156	161	166	171	176	181	186	191	196	3 1.5 4 2.0
875	201	206	211	216	221	226	231	236	240	245	5 2.5
876	250	255	260	265	270	275	280	285	290	295	6 3.0
877	300	305	310	315	320	325	330	335	340	345	7 3.5 8 4.0
878 879	349 399	354 404	359 409	364 414	369 419	374 424	379 429	384 433	389 438	394 443	9 4.5
880	448	453	458	463	468	473	478	483	488	493	
881	498	503	507	512	517	522	527	532	537	542	
882	547	552	557	562	567	571	576	581	586	591	
883	596	601	606	611	616	621	626	680	635	640	
884 885	645 694	650 699	655 704	660 709	665	670 719	675 724	680 729	685 734	689 738	
886	743	748	753	758	714	768	773	778	783	787	4
887	792	797	802	807	812	817	822	827	832	836	1 0.4
888	841	846	851	856	861	866	871	876	880	885	2 0.8
889	890	895	900	905	910	915	919	924	929	934	3 1.2 4 1.6
890	939	944	949	954	959	963	968	973	978	983	5 2.0 6 2.4
891	988	993	998	*002	*007	*012	*017	*022	*027	*032	7 2.8 8 3.2
892 893	95 036 085	041	046	051 100	056 105	061 109	066 114	071 119	075 124	080 129	9 3.6
894	134	139	143	148	153	158	163	168	173	177	
895	182	187	192	197	202	207	211	216	221	226	1
896	231	236	240	245	250	255	260	265	270	274	ļ
897	279	284	289	294	299	303	308	313	318	323	
898 899	328 376	332 381	337	342 390	347 395	352 400	357 405	361 410	366 415	371 419	Ì
900	424	429	434	439	444	448	453	458	463	468	
N.	L. 0	1	2	3	4	5	6	7	8	9	P. P.

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N.	L. 0	1	2	3	4	5	6	7	8	9	P. P.
900	95 424	429	434	439	444	448	453	458	463	468	
901	472	477	482	487	492	497	501	506	511	516	
902	521	525	530	535	540	545	550	554	559	564	
903	569	574	578	583	588	593	598	602	607	612	
904 905	617 665	622 670	626	631 679	636 684	641 689	646 694	650 698	655 703	660 708	
906	713	718	722	727	732	737	742	746	751	756	
907	761	766	770	775	780	785	789	794	799	804	
908	809	813	818	823	828	832	837	842	847	852	
909	856	861	866	871	875	880	885	890	895	899	
910	904	909	914	918	923	928	933	938	942	947	5
911	952 999	957 *004	961 *009	966 *014	971 *019	976 *023	980 *028	985 *033	990 *038	995 *042	1 0.5
912 913	96 047	052	057	061	066	071	076	080	085	090	2 1.0
914	095	099	104	109	114	118	123	128	133	137	3 1.5 4 2.0
915	142	147	152	156	161	166	171	175	180	185	5 2.5
916	190	194	199	204	209	213	218	223	227	232	6 3.0
917	237 284	242 289	246 294	251 298	256 303	261 308	265 313	270 317	275 322	280 327	7 3.5 8 4.0 9 4.5
918 919	284 332	336	341	346	350	355	360	365	369	374	9 4.5
920	379	384	388	393	398	402	407	412	417	421	
921	426	431	435	440	445	450	454	459	464	468	
922	473	478	483	487	492	497	501	506	511	515	
923 924	520 567	525 572	530	534 581	539 586	544 591	548 595	553 600	558 605	562 609	
925	614	619	624	628	633	638	642	647	652	656	
926	661	666	670	675	680	685	689	694	699	703	
927	708	713	717	722	727	731	736	741	745	750	
928 929	755 802	759 806	764 811	769 816	774 820	778 825	783 830	788 834	792 839	797 844	
930	848	853	858	862	867	872	876	881	886	890	
931	895	900	904	909	914	918	923	928	932	937	1 0.4
932	942	946	951	956	960	965	970	974	979	984	1 2 0.8
· 933 934	988 97 035	993	997	*002	*007	*011	*016	*021	*025	*030 077	3 1.2 4 1.6
934	97 035 081	039 086	044	049 095	053 100	058 104	063 109	067 114	072 118	123	5 2.0
936	128	132	137	142	146	151	155	160	165	169	6 2.4 7 2.8
937	174	179	183	188	192	197	202	206	211	216	8 3.2
938	220	225	230	234	239 285	243	248	253 299	257 304	262 308	9 3.6
939	$\frac{267}{313}$	$\frac{271}{317}$	322	327	331	336	340	345	350	354	
941	359	364	368	373	377	382	387	391	396	400	
942	405	410	414	419	424	428	433	437	442	447)
943	451	456	460	465	470	474	479	483	488	493	l l
944	497	502	506	511	516	520	525	529	534	539	l
945 946	543 589	548 594	552 598	557 603	562 607	566 612	571 617	575 621	580 626	585 630	l J
947	635	640	644	649	653	658	663	667	672	676	l i
948	681	685	690	695	699	704	708	713	717	722	
949	727	731	736	740	745	749	754	759	763	768	
950	772	777	782	786	791	795	800	804	809	813	
N.	L.0	1	2	3	4	5	6	7	8	9	P. P.

N.	L. 0	1	2	3	4	5	6	7	8	9	P. P.
50	97 772	777	782	786	791	795	800	804	809	813	
951	818	823	827	832	836	841	845	850	855	859	
952 953	864 909	868	873	877	882	886 932	891	896	900	905	
954	955	914 959	918 964	923 968	928 973	978	937 982	941 987	946 991	950 996	
955	98 000	005	009	014	019	023	028	032	037	041	
956	046	050	055	059	064	068	073	078	082	087	
957 958	091 137	096 141	100 146	105 150	109 155	114 159	118 164	123 168	127 173	132 177	
959	182	186	191	195	200	204	209	214	218	223	
960	227	232	236	241	245	250	254	259	263	268	5
961	272	277	281	286	290	295	299	304	308	313	1 0.5
962 963	318 363	322 367	327 372	331 376	336 381	340 385	345 390	349 394	354 399	358 403	2 1.0
964	408	412	417	421	426	430	435	439	444	448	3 1.5 4 2.0
965	453	457	462	466	471	475	480	484	489	493	5 2.5
966 967	498 543	502 547	507 552	511 556	516 561	520 565	525 570	529 574	534 579	538 583	6 3.0 7 3.5
968	588	592	597	601	605	610	614	619	623	628	8 4.0 9 4.5
969	632	637	641	646	650	655	659	664	668	673	8 2.0
970	677	682	686	691	695	70 0	704	709	713	717	
971	722 767	726	731	735	740 784	744 789	749 793	753 798	758	762	
972 973	811	771 816	776 820	780 825	829	834	838	843	802 847	807 851	
974	856	860	865	869	874	878	883	887	892	896	
975	900	905	909	914	918	923	927	932	936	941	
976 977	945 989	949 994	954 998	958 *003	963 *007	967 *012	972 *016	976 *021	981 *025	985 *029	
978	99 034	038	043	047	052	056	061	065	069	074	
979	078	083	087	092	096	100	105	109	114	118	
980	123	127	131	136	140	145	149	154	158	162	• 4
981	167	171	176	180	185	189	193	198	202	207	1 0.4
982 983	211 255	216 260	220 264	224 269	229 273	233 277	238 282	242 286	247 291	251 295	2 0.8 3 1.2
984	300	304	308	313	317	322	326	330	335	339	4 1.6
985	344	348	352	357	361	366	370	374	379	383	5 2.0 6 2.4
986	388 432	392 436	396	401 445	405 449	410	414	419 463	423 467	427 471	7 2.8
987 988	432 476	480	441 484	445 489	449	454 498	502	506	511	515	8 3.2 9 3.6
989	520	524	528	533	537	542	546	550	555	559	-,
990	564	568	572	577	581	585	590	594	599	603	
991	607	612	616	621	625	629	634	638	642	647	
992 993	651 695	656 699	660 704	664 708	669 712	673 717	677 721	682 726	686 730	691 734	
994	739	743	747	752	756	760	765	769	774	778	
995	782	787	791	795	800	804	808	813	817	822	
996 997	826 870	830 874	835 878	839 883	843 887	848 891	852 896	856 900	861 904	865 909	
998	913	917	922	926	930	935	939	944	948	952	
999	957	961	965	970	974	978	983	987	991	996	
1000	00 000	004	009	013	017	022	026	030	035	039	
N.	L. 0	1	. 2	3	4	5	6	7	8	9	P. P.

N.	L. 0	1	2	3	4	5	6	7	8	9	P. P.
	95 424	429	434	439	444	448	453	458	463	468	
901	472	477	482	487	492	497	501	506	511	516	
902	521	525 574	530	535 583	540 588	545 593	550	554	559	564	
903 904	569 617		578 626	631	636	641	598 646	602 650	607 655	612 660	
905	665	622 670	674	631 679	684	689	694	698	703	708	
906	713	718	722	727	732	737	742	746	751	756	
907	761	766	770	775	780	785	789	794	799	804	
908 909	809 856	813 861	818 866	823 871	828 875	832 880	837	842 890	847 895	852 899	
910	904	909	914	918	923	928	933	938	942	947	
											5
911 912	952	957 *004	961 *009	966 *014	971 *0 19	976 *023	980 *028	985 *033	990 *038	995 *042	1 0.5
913	96 047	052	057	061	066	071	076	080	085	090	2 1.0
914	095	099	104	109	114	118	123	128	133	137	3 1.5 4 2.0
914 915	142	147	152	156	161	166	171	175	180	185	5 2.5
916	190	194	199	204	209	213	218	223	227	232	6 3.0 7 3.5
917 918	237 284	242 289	246 294	251 298	256 303	261 308	265 313	270 317	275 322	280 327	8 4.0
919	332	336	341	346	350	355	360	365	369	374	9 4.5
920	379	384	388	393	398	402	407	412	417	421	
921 922	426	431	435	440	445	450	454	459	464	468	
922	473	478	483	487	492	497	501	506	511	515	
923 924	520 567	525 572	530 577	534 581	539 586	544 591	548 595	553 600	558 605	562 609	
925	614	619	624	628	633	638	642	647	652	656	•
926	661	666	670	675	680	685	689	694	699	703	
927	708	713	717	722	727	731	736	741	745	750	
928 929	755 802	759 806	764 811	769 816	774 820	778 825	783 830	788 834	792 839	797 844	1
930	848	853	858	862	867	872	876	881	886	890	
931	895	900	904	909	914	918	923	928	932	937	1 1 °
932	942	946	951	956	960	965	970	974	979	984	1 0.4
· 933	988	993	997	*002	*007	*011	*016	*021	*025	*030	2 0.8 3 1.2
934	97 035	039	044	049	053	058	063	067	072	077	4 1.6
935	081	086	090	095	100	104	109	114	118	123	5 2.0 6 2.4
936 937	128 174	132 179	137 183	142 188	146 192	151 197	155 202	160 206	165 211	169 216	7 2.8
938	220	225	230	234	239	243	248	253	257	262	8 3.2 9 3.6
939	267	271	276	280	285	290	294	299	304	308	0,100
940	313	317	322	327	331	336	340	345	350	354	
941	359	364	368	373	377	382	387	391	396	400	
942 943	405 451	410 456	414 460	419 465	424 470	428 474	433 479	437 483	442 488	447 493	
944	497	502	506	511	516	520	525	529	534	539	
945	543	548	552	557	562	566	571	575	580	585	Ì
946	589	594	598	603	607	612	617	621	626	630	
947 948	635	640 685	644	649 695	653	658 704	663 708	667 713	672 717	676 722	
949	681 727	731	690 736	740	699 745	749	754	713	763	768	
950	772	777	782	786	791	795	800	804	809	813	
N.	L. 0	1	2	3	4	5	6	7	8	9	P. P.

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N.	L. 0	1	2	3	4	5	6	7	8	9	P. P.
950	97 772	777	782	786	791	795	800	804	809	813	
951	818	823	827	832	836	841	845	850	855	859	
952	864	868	873	877	882	886	891	896	900	905	
953	909	914	918	923	882 928	932	937	941	946	950	
954 955	955 98 000	959 005	964 009	968 014	973 019	978 023	982 028	987 032	991 037	996 041	
956	046	050	055	059	064	068	073	078	082	087	
956 957	091	096	100	105	109	114	118	123	127	132	
958	137	141	146	150	155	159	164	168	173	177	
959	182	186	191	195	200	204	209	214	218	223	
960	227	232	236	241	245	250	254	259	263	268	5
961 962	272 318	277 322	281	286 331	290 336	295 340	299 345	304 349	308	313 358	1 0.5
962 963 964	363	367	327 372	376	381	385	390	394	354 399	403	2 1.0 3 1.5
964	408	412	417	421	426	430	435	439	444	448	4 2.0
965 966	453	457	462	466	471	475	480	484	489	493	5 2.5 6 3.0 7 8.5
967	498 543	502 547	507 552	511 556	516 561	520 565	525 570	529 574	534 579	538 583	7 8.5
968	588	592	597	601	605	610	614	619	623	628	8 4.0 9 4.5
969	632	637	641	646	650	655	659	664	668	673	9 4.5
970	677	682	686	691	695	700	704	709	713	717	
971	722	726	731	735	740	744	749	753	758	762	
972 973	767	771	776	780	784	789 834	793	798	802	807	
973	811 856	816 860	820 865	825 869	829 874	878	838 883	843 887	847 892	851 896	
975	900	905	909	914	918	923	927	932	936	941	
976	945	949	954	958	963	967	972	976	981	985	
977 978	989	994	998	*003	*007	*012	*016	*021	*025	*029	
978	99 034 078	038 083	043 087	047 092	052 096	056 100	061 105	065 109	069 114	074 118	
980	123	127	131	136	140	145	149	154	158	162	. 4
981	167	171	176	180	185	189	193	198	202	207	1 0.4
982 983	211 255	216 260	220 264	224 269	229 273	233 277	238 282	242 286	247 291	251 295	2 0.8 3 1.2
084	300	304	308	313	317	322	326	330	335	339	
985 986 987	344	348	352	357	361	366	370	374	379	383	4 1.6 5 2.0 6 2.4 7 2.8
986	388	392	396	401	405	410	414	419	423 467	427 471	7 2.8
988	432 476	436 480	441 484	445 489	449 493	454 498	458 502	463 506	511	515	8 3.2 9 3.6
989	520	524	528	533	537	542	546	550	555	559	
990	564	568	572	577	581	585	590	594	599	603	
991	607	612	616	621	625	629	634	638	642	647	
992 993	651 695	656 699	660 704	664 708	669 712	673 717	677 721	682 726	686 730	691 734	
994	739	743	747	752	756	760	765	769	774	778	
994 995 996 997	782	787	791	795	800	804	808	813	817	822	
996	826	830	835	839	843	848	852	856	861	865	
997	870 913	874 917	878 922	883 926	887 930	891 935	896 939	900 944	904 948	909 952	
998 999	957	961	965	970	974	978	983	987	991	996	
1000	00 000	004	009	013	017	022	026	030	035	039	
N.	L. 0	1	. 2	3	4	5	6	7	8	9	P. P.

"		L. Sin.	d.	Cpl. 8.	Cpl. T.	L. Tang.	d. c.	L. Cotg.		L
0	0	- 40070						0.5000	0.00000	0
120	$\frac{1}{2}$	6.46373	30103	5.31443 5.31443	5.31443 5.31443	6.46373 6.76476	30103	3.53627	0.00000	
180	3 I	6.94085	17609	5.31443	5.31443	6.94085	17609	3.05915	0.00000	Ĭ
240	ă l	7.06579	12494	5.31443	5.31442	7.06579	12494	2.93421	0.00000	5
300	5	7.16270	9691	5.31443	5.31442	7.16270	9691	2.83730	0.00000	5 5 5
360	6	7.24188	7918	5.31443	5.31442	7.24188	7918	2.75812	0.00000	5
420	7	7.30882	6694 5800	5.31443	5.31442	7.30882	6694 5800	2.69118	0.00000	1 5
480	8	7.36682	5115	5.31443	5.31442	7.36682	5115	2.63318	0.00000	
540		7.41797	4576	5.31443	5.31442	7.41797	4576	2.58203	0.00000	
600 660	10 11	7.46373 7.50512	4139	5.31443 5.31443	5.31442 5.31442	7.46373 7.50512	4139	2.53627 2.49488	0.00000	
720	12	7.54291	3779	5.31443	5.31442	7.54291	3779	2.45709	0.00000	
780	13	7.57767	3476	5.31443	5.31442	7.57767	3476	2.42233	0.00000	
840	14	7.60985	3218 2997	5.31443	5.31442	7.60986	3219 2996	2.39014	0.00000	
900	15	7.63982	2802	5.31443	5.31442	7.63982	2803	2.36018	0.00000	
960	16	7.66784	2633	5.31443	5.31442	7.66785	2633	2.33215	0.00000	
1020 1080	17 18	7.69417 7.71900	2483	5.31443 5.31443	5.31442 5.31442	7.69418 7.71900	2482	2.30582 2.28100	9.99999	
1140	19	7.74248	2348	5.31443	5.31442	7.74248	2348	2.25752	9.99999	
1200	20	7.76475	2227	5.31443	5.31442	7.76476	2228	2.23524	9.99999	4
1260	21	7.78594	2119	5.31443	5.31442	7.78595	2119	2.21405	9.99999	1 3
1320 1380	22	7.80615	2021 1930	5.31443	5.31442	7.80615	2020 1931	2.19385	9.99999	
1440	23 24	7.82545 7.84393	1848	5.31443 5.31443	5.31442 5.31442	7.82546 7.84394	1848	2.17454 2.15606	9.99999	
1500	25	7.86166	1773	5.31443	5.31442	7.86167	1773	2.13833	9.99999	- -3
1560	26	7.87870	1704	5.31443	5.31442	7.87871	1704	2.12129	9.99999	3
1620	27	7.89509	1639	5.31443	5.31442	7.89510	1639	2.10490	9.99999	3
1680	28	7.91088	1579 1524	5.31443	5.31442	7.91089	1579 1524	2.08911	9.99999	3
1740	29	7.92612	1472	5.31443	5.31441	7.92613	1473	2.07387	9.99998	3
1800 1860	30 31	7.94084 7.95508	1424	5.31443 5.31443	5.31441 5.31441	7.94086 7.95510	1424	2.05914 2.04490	9.99998	30
1920	32	7.96887	1379	5.31443	5.31441	7.96889	1379	2.03111	9.99998	2
1980	33	7.98223	1336	5.31443	5.31441	7.98225	1336	2.01775	9.99998	2
2040	34	7.99520	1297 1259	5.31443	5.31441	7.99522	1297 1259	2.00478	9.99998	2
2100	35	8.00779	1223	5.31443	5.31441	8.00781	1223	1.99219	9.99998	2
2160 2220	36 37	8.02002 8.03192	1190	5.31443 5.31443	5.31441 5.31441	8.02004	1190	1.97996 1.96806	9.99998 9.99997	2 2
2280	38	8.04350	1158	5.31443	5.31441	8.03194 8.04353	1159	1.95647	9.99997	2
2340	39	8.05478	1128	5.31443	5.31441	8.05481	1128	1.94519	9.99997	21
2400	40	8.06578	1100	5.31443	5.31441	8.06581	1100	1.93419	9.99997	20
2460	41	8.07650	1072 1046	5.31444	5.31440	8.07653	1072 1047	1.92347	9.99997	19
2520 2580	42 43	8.08696 8.09718	1022	5.31444 5.31444	5.31440 5.31440	8.08700 8.09722	1022	1.91300	9.99997 9.99997	18
2640	44	8.10717	999	5.31444	5.31440	8.10720	998	1.90278 1.89280	9.99996	16
2700	45	8.11693	976	5.31444	5.31440	8.11696	976	1.88304	9.99996	15
2760	46	8.12647	954	5.31444	5.31440	8.12651	955	1.87349	9.99996	14
2820	47	8.13581	934 914	5.31444	5.31440	8.13585	984 915	1.86415	9.99996	13
2880 2940	48	8.14495	896	5.31444	5.31440	8.14500	895	1.85500	9.99996	12
	49	8.15391	877	5.31444	5.31440	8.15395	878	1.84605	9.99996	11
3000 3060	50 51	8.16268 8.17128	860	5.31444 5.31444	5.31439 5.31439	8.16273 8.17133	860	1.83727 1.82867	9.99995	10
3120	52	8.17971	843	5.31444	5.31439	8.17976	843	1.82024	9.99995	8
3180	53	8.18798	827	5.31444	5.31439	8.18804	828	1.81196	9.99995	1 7
3240	54	8.19610	812 797	5.31444	5.31439	8.19616	812 797	1.80384	9.99995	6
3300	55	8.20407		5.31444	5.31439	8.20413	1	1.79587	9.99994	5
3360	56	8.21189	782 769	5.31444	5.31439	8.21195	782 769	1.78805	9.99994	4
3420 3480	57 58	8.21958 8.22713	755	5.31445	5.31439	8.21964	756	1.78036	9.99994	3
3540	59	8.23456	743	5.31445 5.31445	5.31438 5.31438	8.22720 8.23462	742	1.77280 1.76538	9.99994 9.99994	1 2
00	60	8.24186	730	$\frac{5.31445}{5.31445}$	5.31438	8.24192	730	1.75808		-
~ ~ 1		L. Cos.	-d.	0.01770	0.01400		-		9.99993	0
- 1		.u. ∪08.	u.		<u></u>	L. Cotg.	d. c.	L. Tang.	L. Sin.	1 ′

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"	1	L. Sin.	d.	Cpl. S.	Cpl. T.	L. Tang.	d. c.	L. Cotg.	L. Cos.	Π
3600	0	8.24186		5.31445	5.31438	8.24192		1.75808	9.99993	60
3660	1	8.24903	717 706	5.31445	5.31438	8.24910	718 706	1.75090	9.99993	59
3720 3780	3	8.25609 8.26304	695	5.31445	5.31438 5.31438	8.25616 8.26312	696	1.74384 1.73688	9.99993 9.99993	58 57
3840	4	8.26988	684	5.31445 5.31445	5.31437	8.26996	684	1.73004	9.99992	56
3900	5	8.27661	673	5.31445	5.31437	8.27669	673	1.72331	9.99992	55
3960	6	8.28324	663	5.31445	5.31437	8.28332	663	1.71668	9.99992	54
4020	7	8.28977	658 644	5.31445	5.31437	8.28986	654 643	1.71014	9.99992	53
4080 4140	8	8.29621 8.30255	634	5.31445 5.31445	5.31437 5.31437	8.29629 8.30263	634	1.70371 1.69737	9.99992 9.99991	52 51
4200	10	8.30879	624	5.31446	5.31437	8.30888	625	1.69112	9.99991	50
4260	ii	8.31495	616	5.31446	5.31436	8.31505	617	1.68495	9.99991	49
4320	12	8.32103	608	5.31446	5.31436	8.32112	607	1.67888	9.99990	48
4380	13	8.32702	599 590	5.31446	5.31436	8.32711	599 591	1.67289	9.99990	47
4440	14	8.33292	583	5.31446	5.31436	8.33302	584	1.66698	9.99990	46
4500 4560	15 16	8.33875 8.34450	575	5.31446 5.31446	5.31436 5.31435	8.33886 8.34461	575	1.66114 1.65539	9.99990	45 44
4620	17	8.35018	568	5 31446	5.31435	8.35029	568	1.64971	9.99989	43
4680	18	8.35578	560	5.31446	5.31435	8.35590	561	1.64410	9.99989	42
4740	_19	8.36131	558 547	5.31446	5.31435	8.36143	553 546	1.63857	9.99989	41
4800	20	8.36678	539	5.31446	5.31435	8.36689	540	1.63311	9.99988	40
4860 4920	21 22	8.37217 8.37750	533	5.31447 5.31447	5.31434 5.31434	8.37229 8.37762	533	1.62771 1.62238	9.99988 9.99988	39 38
4980	23	8.38276	526	5.31447	5.31434	8.38289	527	1.61711	9.99987	37
5040	24	8.38796	520 514	5.31447	5.31434	8.38809	520 514	1.61191	9.99987	36
5100	25	8.39310	508	5.31447	5.31434	8.39323		1.60677	9.99987	35
5160	26	8.39818	502	5.31447	5.31433	8.39832	509 502	1.60168	9.99986	34
5220 5280	27 28	8.40320 8.40816	496	5.31447 5.31447	5.31433 5.31433	8.40334 8.40830	496	1.59666 1.59170	9.99986 9.99986	33 32
5340	29	8.41307	491	5.31447	5.31433	8.41321	491	1.58679	9.99985	31
5400	30	8.41792	485	5.31447	5.31433	8.41807	486	1.58193	9.99985	30
5460	31	8.42272	480 474	5.31448	5.31432	8.42287	480 475	1.57713	9.99985	29
5520 5580	32 33	8.42746 8.43216	470	5.31448 5.31448	5.31432 5.31432	8.42762 8.43232	470	1.57238 1.56768	9.99984 9.99984	28 27
5640	34	8.43680	464	5.31448	5.31432	8.43696	464	1.56304	9.99984	26
5700	35	8.44139	459	5.31448	5.31431	8.44156	460	1.55844	9.99983	25
5760	36	8.44594	455 450	5.31448	5.31431	8.44611	455	1.55389	9.99983	24
5820	37	8.45044	445	5.31448	5.31431	8.45061	450 446	1.54939	9.99983	23
5880 5940	38 39	8.45489 8.45930	441	5.31448 5.31449	5.31431 5.31431	8.45507 8.45948	441	1.54493 1.54052	9.99982 9.99982	22 21
6000	40	8.46366	436	5.31449	5.31430	8.46385	437	1.53615	9.99982	20
6060	41	8.46799	433	5.31449	5.31430	8.46817	432	1.53183	9.99981	19
6120	42	8.47226	427 424	5.31449	5.31430	8.47245	428 424	1.52755	9.99981	18
6180 6240	43 44	8.47650 8.48069	419	5.31449 5.31449	5.31430 5.31429	8.47669 8.48089	420	1.52331 1.51911	9.99981 9.99980	17 16
	45	8.48485	416	5.31449	5.31429	8.48505	416	1.51495	9.99980	
6300 6360	46	8.48896	411	5.31449	5.31429	8.48917	412	1.51495	9.99979	15 14
6420	47	8.49304	408	5.31450	5.31428	8.49325	408	1.50675	9.99979	13
6480	48	8.49708	404 400	5.31450	5.31428	8.49729	404 401	1.50271	9.99979	12
6540	49	8.50108	396	5.31450	5.31428	8.50130	397	1.49870	9.99978	11
6600 6660	50 51	8.50504 8.50897	393	5.31450 5.31450	5.31428 5.31427	8.50527 8.50920	393	1.49473 1.49080	9.99978 9.99977	10
6720	52	8.51287	390	5.31450	5.31427	8.51310	390	1.48690	9.99977	8
6780	53	8.51673	386 382	5.31450	5.31427	8.51696	386 383	1.48304	9.99977	7
6840	54	8.52055	379	5.31450	5.31427	8.52079	380	1.47921	9.99976	_6
6900	55	8.52434	376	5.31451	5.31426	8.52459	376	1.47541	9.99976	5
6960 7020	56 57	8.52810 8.53183	373	5.31451 5.31451	5.31426 5.31426	8.52835 8.53208	373	1.47165 1.46792	9.99975 9.99975	3
7080	58	8.53552	369	5.31451	5.31425	8.53578	370	1.46422	9.99974	2
7140	59	8.53919	367 363	5.31451	5.31425	8.53945	367 363	1.46055	9.99974	
7200	60	8.54282		5.31451	5.31425	8.54308		1.45692 -	9.99974	0
	I [L. Cos.	d.			L. Cotg.	d. c.	L. Tang.	L. Sin.	,

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"		L. Sin.	d.	Cpl. 8.	Cpl. T.	L. Tang.	d. c.			
7200	9	8.54282	360	5.31451	5.31425	8.54308	361	1.45692	9.9997 9.9997	
7260 7320	1 2	8.54642 8.54999	357	5.31451 5.31452	5.31425 5.31424	8.54669 8.55027	358	1.45331 1.44973	9.9997	
7320	3	8.55354	355	5.31452	5.31424	8.55382	355	1.44973	9.9997	زاز
7440	4	8.55705	351	5.31452	5.31424	8.55734	352	1.44266	9.9997	2 1
7500	5	8.56054	349	5.31452	5.31423	8.56083	349	1.43917	9.9997	1
7560	6	8.56400	346	5.31452	5.31423	8.56429	346	1.43571	9.9997	1 1
7620	7	8.56743	343 341	5.31452	5.31423	8.56773	344 341	1.43227	9.99970	
7680 7740	8 9	8.57084	337	5.31453 5.31453	5.31422 5.31422	8.57114 8.57452	338	1.42886	9.9997	
7740		8.57421	336	5.31453		8.57452	336	1.42548	9.9996	
7800 7860	10 11	8.57757 8.58089	332	5.31453 5.31453	5.31422 5.31421	8.57788 8.58121	333	1.42212 1.41879	9.9996 9.9996	
7860 7920	11 12	8.58419	330	5.31453	5.31421	8.58121 8.58451	330	1.41879	9.9996	
7980	13	8.58747	328	5.31453	5.31421	8.58779	328	1.41221	9.9996	7 4
8040	14	8.59072	325	5.31454	5.31421	8.59105	326	1.40895	9.99967	7 4
8100	15	8.59395	323	5.31454	5.31420	8.59428	323	1.40572	9.99967	7 4
8160	16	8.59715	320 318	5.31454	5.31420	8.59749	321	1.40251	9.99966	6 4
8220	17	8.60033	318 316	5.31454	5.31420	8.60068	319 316	1.39932	9.99966	5 4
8280	18	8.60349	313	5.31454	5.31419	8.60384	316	1.39616	9.99965	
8340	19	8.60662	311	5.31454	5.31419	8.60698	311	1.39302	9.99964	- 1-
8400	20	8.60973 8.61282	309	5.31455 5.31455	5.31418 5.31418	8.61009 8.61319	310	1.38991 1.38681	9.99964 9.99963	
8460 8520	21 22	8.61282 8.61589	307	5.31455 5.31455	5.31418	8.61319 8.61626	307	1.38681 1.38374	9.99963	
8520 8580	23	8.61894	305	5.31455	5.31418	8.61931	305	1.38374	9.99963	
8640	24	8.62196	302	5.31455	5.31417	8.62234	303	1.37766	9.99962	
8700	25	8.62497	301	5.31455	5.31417	8.62535	301	1.37465	9.99961	3
8760	26	8.62795	298	5.31456	5.31416	8.62834	299	1.37166	9.99961	3
8820	27	8.63091	296	5.31456	5.31416	8.63131	297	1.36869	9.99960	3
8880	28	8.63385	294 293	5.31456	5.31416	8.63426	295 292	1.36574	9.99960	33
8940	29	8.63678	293 290	5.31456	5.31415	8.63718	292	1.36282	9.99959	31
9000	30	8.63968	288	5.31456	5.31415	8.64009	289	1.35991	9.99959	30
9060	31	8.64256 8.64543	287	5.31456 5.31457	5.31415	8.64298	287	1.35702	9.99958	29
9120 9180	32 33	8.64543 8.64827	284	5.31457 5.31457	5.31414 5.31414	8.64585 8.64870	285	1.35415 1.35130	9.99958 9.99957	28 27
9180	33	8.64827 8.65110	283	5.31457 5.31457	5.31414	8.65154	284	1.35130	9.99957	26
9300	35	8.65391	281	5.31457	5.31413	8.65435	281	1.34565	9.99956	25
9360	36	8.65670	279	5.31457	5.31413	8.65715	280	1.34285	9.99955	24
9420	37	8.65947	277	5.31458	5.31412	8.65993	278	1.34007	9.99955	23
9480	38	8.66223	276	5.31458	5.31412	8.66269	276	1.33731	9.99954	22
9540	39	8.66497	274 272	5.31458	5.31412	8.66543	274 273	1.33457	9.99954	21
9600	40	8.66769	272	5.31458	5.31411	8.66816	271	1.33184	9.99953	20
9660	41	8.67039	270 269	5.31458	5.31411	8.67087	271 269	1.32913	9.99952	19
9720	42	8.67308	267	5.31459 5.31459	5.31410 5.31410	8.67356 8.67624	268	1.32644 1.32376	9.99952	18
9780 9840	43 44	8.67575 8.67841	266	5.31459	5.31410	8.67624	266	1.32376	9.99951 9.99951	17 16
9900	45	8.68104	263	5.31459	5.31410	8.68154	264	1.31846	9.99950	15
9900	45 46	8.68104 8.68367	263	5.31459 5.31459	5.31409	8.68154	263	1.31846	9.99950	15 14
10020	40	8.68627	260	5.31460	5.31408	8.68678	261	1.31322	9.99949	13
10080	48	8.68886	259	5.31460	5.31408	8.68938	260	1.31062	9.99948	12
10140	49	8.69144	258 256	5.31460	5.31408	8.69196	258 257	1.30804	9.99948	11
10200	50	8.69400		5.31460	5.31407	8.69453		1.30547	9.99947	10
10260	51	8.69654	254 253	5.31460	5.31407	8.69708	255 254	1.30292	9.99946	9
10320	52	8.69907	252	5.31461	5.31406	8.69962	252	1.30038	9.99946	8
10380 10440	53 54	8.70159 8.70409	250	5.31461 5.31461	5.31406 5.31405	8.70214 8.70465	251	1.29786 1.29535	9.99945 9.99944	7
			249	THE RESERVE AND THE	5.31405		249			_
10500 10560	55 56	8.70658 8.70905	247	5.31461 5.31461	5.31405 5.31405	8.70714 8.70962	248	1.29286 1.29038	9.99944 9.99943	5
10620	56 57	8.70905 8.71151	246	5.31461	5.31405	8.70962 8.71208	246	1.29038	9.99943 9.99942	3
10680	58	8.71395	244	5.31462	5.31404	8.71453	245	1.28547	9.99942	2
10740	59	8.71638	243	5.31462	5.31403	8.71697	244	1.28303	9.99941	í
10800	60	8.71880	242	5.31462	5.31403	8.71940	243	1.28060	9.99940	ó
1		L. Cos.	d.		1	L. Cotg.	4 0	L. Tang.	L. Sin.	-,
	<u></u>	005.	<u>u.</u>	<u></u>		. 11. Corg.	u. C.	TO TOTIE!	n. 2111.	ن

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	'	L. Sir	ı. d.	L. Tang.	d. c.	L. Cotg.	L. Cos.	1	Ι	I	P. P.	
Γ	0	8.7188	0 240	8.71940	241	1.28060	9.99940	60		238	234	229
1	1 2	8.7212 8.7235	0 239	8.72181 8.72420	239	1.27819	9.99940	59	6	23.8	23.4	22.9
1	ร์	8.7259	7 200	8.72659	239	1.27580 1.27341	9.99939 9.99938	58 57	7	27.8	27.3	26.7
١	4	3.7283	A 237	8.72896	237	1.27104	9.99938	56	8	31.7 35.7	31.2 35.1	30.5 34.4
r	5	8.7306	235	8.73132	236	1.26868	9.99937	55	10	39.7	39.0	38.2
١	6	8.7330	3 234	8.73366	234 234	1.26634	9.99936	54	20	79.3	78.0	76.3
١	7	8.7353 8.7376		8.73600 8.73832	232	1.26400	9.99936	53	30 40	119.0	117.0	114.5
١	8	8.7399	7 230	8.74063	231	1.26168 1.25937	9.99935 9.99934	52 51	50	158.7 198.3	156.0 195.0	152.7 190.8
١	10	8.7422	G 229	8.74292	229	1.25708	9.99934	50	۱۳۰			
	iĭ	8.7445	4 2228	8.74521	229	1.25479	9.99933	49		225	220	216
	12	8.7468	0 220	8.74748	227 226	1.25252	9.99932	48	6	22.5 26.3	22.0 25.7	21.6 25.2
	13	8.7490	904	8.74974	225	1.25026	9.99932	47	8	30.0	29.3	28.8
	14 15	8.7513 8.7535		8.75199	224	1.24801	$\frac{9.99931}{9.99930}$	46	9	33.8	33.0	32.4
	16	8.7557	5 222	8.75423 8.75645	222	1.24577 1.24355	9.99930	45	10 20	37.5	36.7	36.0 72.0
	17	8.7579	5 22U	8.75867	222	1.24133	9.99929	43	30	75.0 112.5	73.3 110.0	108.0
	18	8.7601		8.76087	220 219	1.23913	9.99928	42	40	150.0	146.7	144.0
	19	8.7623	217	8.76306	219	1.23694	9.99927	41	50	187.5	183.3	180.0
	20	8.7645 8.7666		8.76525	217	1.23475	9.99926	40		212	208	204
	21 22	8.7688	010	8.76742 8.76958	216	1.23258 1.23042	9.99926 9.99925	39 38	6	21.2	20.8	20.4
	23	8.7709	7 214	8.77173	215	1.22827	9.99924	37	7	24.7	24.3	23.8
	24	8.7731		8.77387	214 213	1.22613	9.99923	36	8	28.3 31.8	27.7 31.2	27.2 30.6
	25	8.7752	2 011	8.77600	211	1.22400	9.99923	35	10	35.3	34.7	34.0
	26 27		0 1 2	8.77811 8.78022	211	1.22189	9.99922	34 33	20	70.7	69.3	68.0
	28	8.7815	2 209	8.78232	210	1.21978 1.21768	9.99921 9.99920	32	30	106.0	104.0	102.0
	29			8.78441	209 208	1.21559	9.99920	31	40 50	141.3 176.7	138.7 173.3	136.0 170.0
	30		8 000	8.78649	206	1.21351	9.99919	30				
	31		2 005	8.78855	206	1.21145	9.99918	29 28	6	201 20.1	197 19.7	19.3
	3		204	8.79061 8.79266	205	1.20939 1.20734	9.99917 9.99917	27	7	23.5	23.0	22.5
	3		ഭ∣203	8.79470	204	1.20530	9.99916	26	8	26.8	26.3	25.7
	3	8.7958	202	8.79673	203	1.20327	9.99915	25	9	30.2	29.6 32.8	29.0
	1 3			8.79875	202 201	1.20125	9.99914	24	10 20	33.5 67.0	65.7	32.2 64.3
	3		~ 100	8.80076 8.80277	201	1.19924 1.19723	9.99913 9.99913	23 22	30	100.5	98.5	96.5
	3		g 199	8.80476	199	1.19524	9.99912	21	40	134.0	131.3	128.7
	4	8.8058	197	8.80674	198	1.19326	9.99911	20	50	167. 5	164.2	160.8
	4	1 8.8078		8.80872	198 196	1.19128	9.99910	19		189	185	181
		$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	105	8.81068	196	1.18932	9.99909	18	6	18.9	18.5	18.1
		3 8.8117 4 8.8136	7 194	8.81264 8.81459	195	1.18736 1.18541	9.99909 9.99908	17 16	7 8	22.1 25.2	21.6 24.7	$21.1 \\ 24.1$
	I	5 8.8156	193	8.81653	194	1.18347	9.99907	15	l ŏ	28.4	27.8	27.2
	4	6 8.8175	2 192	8.81846	193	1.18154	9.99906	14	10	31.5	30.8	30.2
}		7 8.8194	4 192	8.82038	192 192	1.17962	9.99905	13	20 30	63.0	61.7 92.5	60.3 90.5
		18 8.8213 19 8.8232	7	8.82230 8.82420	190	1.17770 1.17580	9.99904 9.99904	12 11	40	94.5 126.0	123.3	120.7
	I	0 8.8251	180	8.82610	190	1.17390	9.99903	10	50	157.5	154.2	150.8
		1 8.8270	11 188	8.82799	189	1.17201	9.99903	9				1.1
_] [52 8.8288	8 187	8.82987	188	1.17013	9.99901	8	6	0.4	3 2 0.3 0.2	
-		8.8307		8.83175	188 186	1.16825	9.99900	7	7	0.5	$0.4 \mid 0.2$	0.1
	1_	8.8326	195	8.83361	186	1.16639	9.99899	6	8	0.5	$0.4 \mid 0.3$	
		55 8.8344 56 8.8363	n 184	8.83547 8.83732	185	1.16453 1.16268	9.99898 9.99898	5 4	9 10		0.5 0.3 0.5 0.3	
	- 13	57 8.8381	2 183	8.83916	184	1.16084	9.99897	3	20		1.0 0.7	
	.	58 8.8399	6 183	8.84100	184 182	1.15900	9.99896	2	30	2.0	1.5 1.0	
	-	59 8.8417	181	8.84282	182	1.15718	9.99895	1	40 50		$\begin{array}{c c} 2.0 & 1.3 \\ 2.5 & 1.7 \end{array}$	
	12	8.8435	8	8.84464		1.15536	9.99894	0	- 30			- 0.0
	L	L. Co	8. d.	L. Cotg.	a. c.	L.Tang.	L. Sin.			P	P. P.	

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7	L. Sin.	d.	L. Tang.	d. c.	L. Cotg.	L. Cos.	1		P	. P.	
0	8.84358	101	8.84464	182	1.15536	9.99894	60		181	179	1 177
1 1	8.84539	181 179	8.84646	180	1.15354	9.99893 9.99892	59 58	6	18.1	17.9	17.7
3	8.84718 8.84897	179	8.84826 8.85006	180	1.15174 1.14994	9.99891	57	7	21.1	20.9	20.7 23.6
4	8.85075	178	8.85185	179	1.14815	9.99891	56	8	24.1 27.2	23.9 26.9	26.6
5	8.85252	177	8.85363	178	1.14637	9.99890	55	10	30.2	29.8	29.5
6	8.85429	177 176	8.85540	177 177	1.14460	9.99889	54	20	60.3	59.7	59.0
7	8.85605	175	8.85717	176	1.14283	9.99888	53	30 40	90.5 120.7	89.5 119.3	88.5 118.0
8 9	8.85780 8.85955	175	8.85893 8.86069	176	1.14107 1.13931	9.99887 9.99886	52 51	50	150.8	149.2	147.5
10	8.86128	173	8.86243	174	1.13757	9.99885	50				•
lii	8.86301	173	8.86417	174	1.13583	9.99884	49	6	175 17.5	17.3	171 17.1
12	8.86474	173 171	8.86591	174 172	1.13409	9.99883	48	7	20.4	20.2	20.0
13	8.86645 8.86816	171	8.86763 8.86935	172	1.13237 1.13065	9.99882 9.99881	47 46	8	23.3	23.1	22.8
14		171		171	1.12894	9.99880	45	9	26.3	26.0	25.7
15 16	8.86987 8.87156	169	8.87106 8.87277	171	1.12723	9.99879	44	10 20	29.2 58.3	28.8 57.7	28.5 57.0
17	8.87325	169	8.87447	170	1.12553	9 99879	43	30	87.5	86.5	85.5
18	8.87494	169 167	8.87616	169 169	1.12384	9.99878	42	40	116.7	115.3	114.0
19	8.87661	168	8.87785	168	1.12215	9.99877	41	50	145.8	144.2	142.5
20	8.87829	166	8.87953	167	1.12047	9.99876 9.99875	40 39		168	186	164
21 22	8.87995 8.88161	166	8.88120 8.88287	167	1.11880 1.11713	9.99874	38	6	16.8	16.6	16.4
23	8.88326	165	8.88453	166	1.11547	9.99873	37	7	19.6	19.4	19.1
24	8.88490	164 164	8.88618	165 165	1.11382	9.99872	36	8	22.4 25.2	22.1 24.9	21.9 24.6
25	8.88654	163	8.88783	165	1.11217	9.99871 9.99870	35	10	28.0	27.7	27.3
26	8.88817	163	8.88948	163	1.11052		34	20	56.0	55.3	54.7
27 28	8.88980 8.89142	162	8.89111 8.89274	163	1.10889 1.10726	9.99869 9.99868	33 32	30	84.0	83.0	82.0
29	8.89304	162	8.89437	163	1.10563	9.99867	31	40 50	112.0 140.0	110.7 138.3	109.3 136.7
30	8.89464	160	8.89598	161	1.10402	9.99866	30	"			
31	8.89625	161 159	8.89760	162 160	1.10240	9.99865	29	6	162 16.2	15.9	15.7 15.7
32	8.89784 8.89943	159	8.89920 8.90080	160	1.10080 1.09920	9.99864 9.99863	28 27	7	18.9	18.6	18.3
34	8.90102	159	8.90240	160	1.09760	9.99862	26	8	21.6	21.2	20.9
35	8.90260	158	8,90399	159	1.09601	9.99861	25	9	24.3	23.9	23.6
36	8.90417	157	8.90557	158	1.09443	9.99860	24	10 20	27.0 54.0	26.5 53.0	26.2 52.3
37	8.90574	157 156	8.90715	158 157	1.09285	9.99859	23 22	30	81.0	79.5	78.5
38 39	8.90730 8.90885	155	8.90872 8.91029	157	1.09128	9.99858 9.99857	21	40	108.0	106.0	104.7
40	8.91040	155	8.91185	156	1.08815	9.99856	20	50	135.0	132.5	130.8
41	8.91195	155	8.91340	155	1.08660	9.99855	19	1	155	153	151
42	8.91349	154 153	8.91495	155 155	1.08505	9.99854	18	6	15.5	15.3	15.1
43	8.91502	153	8.91650 8.91803	153	1.08350 1.08197	9.99853 9.99852	17 16	7 8	18.1 20.7	17.9 20.4	17.6 20.1
44	8.91655	152	8.91957	154	1.08043	9.99851	15	9	23.3	23.0	22.7
45 46	8.91807 8.91959	152	8.92110	153	1.07890	9.99850	14	10	25.8	25.5	25.2
47	8.92110	151	8.92262	152	1.07738	9.99848	13	20	51.7	51.0	50.3
48	8.92261	151 150	8.92414	152 151	1.07586	9.99847	12	30 40	77.5 103.3	76.5 102.0	75.5 100.7
49	8.92411	150	8.92565	151	1.07435	9.99846	_11	5ŏ	129.2	127.5	125.8
50	8.92561 8.92710	149	8.92716 8.92866	150	1.07284 1.07134	9.99845 9.99844	10				` l
51 52	8.92859	149	8.93016	150	1.06984	9.99843	8	6	149 14.9	14.7	0.1
53	8.93007	148	8.93165	149	1.06835	9.99842	7	ŏ	17.4	17.2	
54	8.93154	147 147	8.93313	148 149	1.06687	9.99841	6	8	19.9	19.6	0.1
55	8.93301	147	8.93462	147	1.06538	9.99840	5	9 10	22.4 24.8	22.1 24.5	0.2
56 57	8.93448 8.93594	146	3.93609 8.93756	147	1.06391 1.06244	9.99839 9.99838	3	20	49.7	49.0	0.2
58	8.93740	146	8.93903	147	1.06097	9.99837	2	30	74.5	73.5	0.5
59	8.93885	145 145	8.94049	146 146	1.05951	9.99836	ī	40	99.3	98.0	
60	8.94030	140	8.94195	140	1.05805	9.99834	0	50	124.2	122.5	0.8
	L. Cos.	d.	L. Cotg.	d. c.	L.Tang.	L. Sin.	/		P	. P.	

7	L. Sin.	d.	L.Tang.	d. c.	L. Cotg.	L. Cos.		1	I	P. P.	
0	8.94030		8.94195		1.05805	9.99834	60		145	143	1.41
ĭ	8.94174	144	8.94340	145	1.05660	9.99833	59	6 1	14.5	14.3	14.1
2	8.94317	143	8.94485	145 145	1.05515	9.99832	58	7	16.9	16.7	16.5
3	8.94461	144 142	8.94630	143	1.05370	9.99831	57	8	19.3	19.1	18.8
4	8.94603	143	8.94773	144	1.05227	9.99830	56	9	21.8	21.5	21.2
5	8.94746	141	8.94917	143	1.05083	9.99829	55	10	24.2	23.8	23.5
6	8.94887	142	8.95060	142	1.04940	9.99828	54	20	48.3	47.7	47.0
7	8.95029	141	8.95202	142	1.04798	9.99827	53	30	72.5	71.5	70.5
8	8.95170 8.95310	140	8.95344 8.95486	142	1.04656 1.04514	9.99825 9.99824	52 51	40 50	96.7 120.8	95.3 119.2	94.0 117.5
		140		141				00 1	120.0	115.2	117.0
10	8.95450 8.95589	139	8.95627 8.95767	140	1.04373 1.04233	9.99823 9.99822	50 49		139	138	136
11 12	8.95728	139	8.95908	141	1.04233	9.99821	48	6	13.9	13.8	13.6
13	8.95867	139	8.96047	139	1.03953	9.99820	47	7 !	16.2	16.1	15.9
14	8.96005	138	8.96187	140	1.03813	9.99819	46	8	18.5	18.4	18.1
15	8.96143	138	8.96325	138	1.03675	9.99817	45	10	20.9 28.2	20.7 23.0	20.4 22.7
16	8.96280	137	8.96464	139	1.03536	9.99816	44	20	46.3	46.0	45.3
17	8.96417	137	8.96602	138	1.03398	9.99815	43	30	69.5	69.0	68.0
18	8.96553	136	8.96739	137	1.03261	9.99814	42	40	92.7	92.0	90.7
19	8.96689	136	8.96877	138	1.03123	9.99813	41	50	115.8	115.0	113.3
20	8.96825	136	8.97013	136	1.02987	9.99812	40				
21	8.96960	135	8.97150	137	1.02850	9.99810	39		135	133	131
22	8.97095	135	8.97285	135	1.02715	9.99809	38	67.	13.5	13.3	13.1
23	8.97229	134 134	8.97421	136 135	1.02579	9.99808	37	8	15.8 18.0	15.5 17.7	15.3 17.5
24	8.97363	133	8.97556	135	1.02444	9.99807	36	9	20.3	20.0	19.7
25	8.97496		8.97691		1.02309	9.99806	35	10	22.5	22.2	21.8
26	8.97629	133 133	8.97825	134 134	1.02175	9.99804	34	20	45.0	44.3	43.7
27	8.97762	132	8.97959	133	1.02041	9.99803	33	30	67.5	66.5	65.5
28 29	8.97894 8.98026	132	8.98092 8.98225	133	1.01908 1.01775	9.99802 9.99801	32 31	40	90.0	88.7	87.3
		131		133				50	112.5	110.8	109.2
30	8.98157	131	8.98358	132	1.01642	9.99800 9.99798	30 29		129	128	126
31 32	8.98288 8.98419	131	8.98490 8.98622	132	1.01510 1.01378	9.99798	28	61	12.9	12.8	12.6
33	8.98549	130	8.98753	131	1.01378	9.99796	27	7	15.1	14.9	14.7
34	8.98679	180	8.98884	131	1.01116	9.99795	26	8	17.2	17.1	16.8
35	8.98808	129	8.99015	131	1.00985	9.99793	25	9	19.4	19.2	18.9
36	8.98937	129	8.99145	130	1.00855	9.99792	24	10	21.5	21.3	21.0
37	8.99066	129	8.99275	130	1.00725	9.99791	23	20	43.0	42.7	42.0
38	8.99194	128	8.99405	130	1.00595	9.99790	22	30 40	64.5 86.0	64.0 85.3	63.0 84.0
39	8.99322	128	8.99534	129	1.00466	9.99788	21	50	107.5	106.7	105.0
40	8.99450	128	8.99662	128	1.00338	9.99787	20	00 (101.0	100.7	100.0
41	8.99577	127	8.99791	129	1.00209	9.99786	19		125	123	122
42	8.99704	127	8.99919	128	1.00081	9.99785	18	6	12.5	12.3	12.2
43	8.99830	126 126	9.00046	127 128	0.99954	9.99783	17	7	14.6	14.4	14.2
44	8.99956	126	9.00174	127	0.99826	9.99782	16	8	16.7	16.4	16.3
45	9.00082	125	9.00301	126	0.99699	9.99781	15	10	18.8 20.8	18.5 20.5	18.3 20.3
46	9.00207	125	9.00427	126	0.99573	9.99780	14	20	41.7	41.0	40.7
47	9.00332	123	9.00558	126	0.99447	9.99778	13	30	62.5	61.5	61.0
48	9.00456	125	9.00679 9.00805	126	0.99321 0.99195	9.99777 9.99776	12 11	40	83.3	82.0	81.3
49	9.00581	123		125	I			50	104.2	102.5	101.7
50	9.00704	124	9.00930	125	0.99070 0.98945	9.99775 9.99773	10		101	1 100	, , 1
51	9.00828 9.00951	123	9.01055 9.01179	124	0.98945	9.99773	8	6	121 12.1	12.0	0.1
52 53	9.00951	123	9.01179	124	0.98697	9.99771	7	7	14.1	14.0	0.1
54	9.01196	122	9.01427	124	0.98573	9.99769	6	8	16.1	16.0	
55	9.01318	122	9.01550	123	0.98450	9.99768	5	9	18.2	18.0	0.2
56	9.01318	122	9.01673	123	0.98327	9.99767	4	10	20.2	20.0	0.2
57	9.01561	121	9.01796	123	0.98204	9.99765	3	20	40.3	40.0	0.3
58	9.01682	121	9.01918	122	0.98082	9.99764	2	30	60.5		
59	9.01803	121	9.02040	122	0.97960	9.99763	1	40	80.7		
60	9.01923	120	9.02162	122	0.97838	9.99761	0	50	100.8	100.0	0.8
	L. Cos.	d.	L. Cotg.	de			 -	_	ī	. P.	
L	L. COB.	1 u.	IT. COIR.	а. с.	D. I will.	1 M. OIII.		<u></u>			

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1	L. Sin.	d.	L.Tang.	d. c.	L. Cotg.	L. Cos.	İ	1	P	. P.	
0	9.01923	120	9.02162	121	0.97838	9.99761	60		121	120	
1 2	9.02043 9.02163	120	9.02283 9.02404	121	0.97717 0.97596	9.99760 9.99759	59 58	6	12.1	12.0	11.9
3	9.02283	120	9.02525	121	0.97475	9.99757	57	7 8	14.1	14.0	13.9
4	9.02402	119 118	9.02645	120 121	0.97355	9.99756	56	9	16.1 18.2	16.0 18.0	15.9
5	9.02520		9.02766	119	0.97234	9.99755	55	10	20.2	20.0	19.8
6	9.02639	119 118	9.02885	120	0.97115	9.99753	54	20	40.3	40.0	39.7
8	9.02757 9.02874	117	9.03005 9.03124	119	0.96995 0.96876	9.99752 9.99751	53 52	30 40	60.5 80.7	60.0 80.0	59.5 79.3
ÿ	9.02992	118	9.03242	118	0.96758	9.99749	51	50	100.8		
10	9.03109	117	9.03361	119	0.96639	9.99748	50	" '			•
11	9.03226	117 116	9.03479	118 118	0.96521	9.99747	49	6	!!8 11.8	11.7	11.6
12 13	9.03342 9.03458	116	9.03597 9.03714	117	0.96403 0.96286	9.99745 9.99744	48 47	lÿ	13.8	13.7	13.5
14	9.03574	116	9.03832	118	0.96168	9.99742	46	8	15.7 17.7	15.6	15.5
15	9.03690	116	9.03948	116	0.96052	9.99741	45	1,9	17.7	17.6	17.4
16	9.03805	115	9.04065	117	0.95935	9.99740	44	10 20	19.7 39.3	19.5 39.0	19.3 38.7
17	9.03920	115 114	9.04181	116 116	0.95819	9.99738	43	30	59.0	58.5	58.0
18 19	9.04034 9.04149	115	9.04297 9.04413	116	0.95703 0.95587	9.99737 9.99736	42 41	40		78.0	77.3
20	9.04262	113	9.04528	115	0.95472	9.99734	40	50	98.3	97.5	96.7
21	9.04376	114	9.04643	115	0.95357	9.99733	39	l	115	114	113
22	9.04490	114 113	9.04758	115	0.95242	9.99731	38	6		11.4	11.3
23	9.04603	112	9.04873	115 114	0.95127 0.95013	9.99730 9.99728	37	8	13.4 15.3	13.3 15.2	13.2 15.1
24	9.04715	113		114			36	9	17.3	17.1	17.0
25 26	9.04828 9.04940	112	9.05101 9.05214	113	0.94899 0.94786	9.99727 9.99726	35 34	10	19.2	19.0	18.8
27	9.05052	112	9.05328	114	0.94672	9.99724	33	20 30	38.3	38.0	37.7
28	9.05164	112 111	9.05441	113 112	0.94559	9.99723	32	40	57.5 76.7	57.0 76.0	56.5 75.3
29	9.05275	iii	9.05553	113	0.94447	9.99721	31	50	95.8	95.0	94.2
30	9.05386 9.05497	111	9.05666	112	0.94334	9.99720	30 29		•		
31 32	9.05607	110	9.05778 9.05890	112	0.94222 0.94110	9.99718 9.99717	28	6	11.2	11.1	11.0
33	9.05717	110	9.06002	112	0.93998	9.99716	27	7	13.1	13.0	12.8
34	9.05827	110 110	9.06113	111 111	0.93887	9.99714	26	8		14.8	14.7
35	9.05937	109	9.06224	111	0.93776	9.99713	25	9 10	16.8 18.7	16.7 18.5	16.5 18.3
36 37	9.06046 9.06155	109	9.06335 9.06445	110	0.93665 0.93555	9.99711 9.99710	24 23	20	37.3	37.0	36.7
38	9.06264	109	9.06556	111	0.93444	9.99708	22	30	56.0	55.5	55.0
39	9.06372	108 109	9.06666	110	0.93334	9.99707	21	40 50	74.7 93.3	74.0 92.5	73.3
40	9.06481	108	9.06775	109	0.93225	9.99705	20	30	90.0	92.0	91.7
41	9.06589	107	9.06885	110 109	0.93115	9.99704	19		109	108	107
42	9.06696 9.06804	108	9.06994 9.07103	109	0.93006 0.92897	9.99702 9.99701	18 17	6 7	10.9 12.7	10.8 12.6	10.7 12.5
44	9.06911	107	9.07211	108	0.92789	9.99699	16	l ś	14.5	14.4	14.3
45	9.07018	107	9.07320	109	0.92680	9.99698	15	9	16.4	16.2	16.1
46	9.07124	106 107	9.07428	108 108	0.92572	9.99696	14	10	18.2	18.0	17.8
47	9.07231 9.07337	106	9.07536 9.07643	107	0.92464 0.92357	9.99695 9.99693	13 12	20 30	36.3 54.5	36.0 54.0	35.7 53.5
49	9.07442	105	9.07751	108	0.92249	9.99692	11	40	72.7	72.0	71.3
50	9.0/548	106	9.07858	107	0.92142	9.99690	10	50	90.8	90.0	89.2
51	9.07653	105	9.07964	106	0.92036	9.99689	9		100	105	104
52	9.07758	105 105	9.08071	107 106	0.91929	9.99687	8	6	10.6	10.5	10.4
53 54	9.07863 9.07968	105	9.08177 9.08283	103	0.91823 0.91717	9.99686 9.99684	7 6	7	12.4	12.3	12.1
55	9.08072	104	9 08389	106	0.91611	9.99683	5	8	14.1 15.9	14.0 15.8	13.9 15.6
56	9.08175	104	9.08495	106	0.91505	9.93681	4	10	17.7	17.5	17.3
57	9.08280	104 103	9.08600	105 105	0.91400	9.99680	3	20	35.3	35.0	34.7
58 59	9.08383 9.08486	103	9.08/05	105	0.91295 0.91190	9.99678 9.99677	$\frac{2}{1}$	30 40	53.0	52.5	52.0
60	9.08589	103	9.08914	104	0.91190		-	50	70.7 88.3	70.0 87.5	69.3 86.7
100	L. Cos.	<u>d.</u>		d. c.		9.99675	-,' -	<u>~</u> "			
	17. COS.	u.	L. Cotg.	a. c.	L.Tang.	L. Sin.	<u></u>	<u> </u>	P	. P.	

•	L. Sin.	·d.	L.Tang.	d. c.	L. Cotg.	L. Cos.	1	P. P.
0	9.08589		9.08914		0.91086	9.99675	60	
ĭ	9.08692	103	9.09019	105	0.90981	9.99674	59	105 104 103
	9.08795	103	9.09123	104	0.90877	9.99672	58	6 10.5 10.4 10.3
3	9.08897	102	9.09227	104	0.90773	9.99670	57	7 12.3 12.1 12.0
4	9.08999	102	9.09330	103	0.90670	9.99669	56	8 14.0 13.9 13.7
5	9.09101	102	9.09434	104	0.90566			9 15.8 15.6 15.5
	9.09202	101	9.09434	103	0.90366	9.99667	55	10 17.5 17.3 17.2
6	9.09304	102	9.09640	103	0.90360	9.99666 9.99664	54	20 35.0 34.7 34.3
8	9.09405	101	9.09742	102	0.90258	9.99663	53 52	30 52.5 52.0 51.5
ŝ	9.09506	101	9.09845	103	0.90155	9.99661	51	40 70.0 69.3 68.7
		100		102				50 87.5 86.7 85.8
10	9.09606	101	9.09947	102	0.90053	9.99659	50	102 101 100
11	9.09707	100	9.10049	101	0.89951	9.99658	49	6 10.2 10.1 10.0 6 10.2 10.1 10.0
12	9.09807	100	9.10150	102	0.89850	9.99656	48	7 11.9 11.8 11.7
13	9.09907	99	9.10252	101	0.89748	9.99655	47	8 13.6 13.5 13.3
14	9.10006	100	9.10353	101	0.89647	9.99653	46	9 15.3 15.2 15.0
15	9.10106		9.10454		0.89546	9.99651	45	10 17.0 16.8 16.7
16	9.10205	99	9.10555	101	0.89445	9.99650	44	20 34.0 33.7 33.3
17	9.10304	99	9.10656	101	0.89344	9.99648	43	30 51.0 50.5 50.0
18	9.10402	98	9.10756	100	0.89244	9.99647	42	40 68.0 67.3 66.7
19	9.10501	99	9.10856	100	0.89144	9.99645	41	50 85.0 84.2 83.3
20	9.10599	98	9.10956	100	0.89044	9.99643	40	55 55.5 54.2 55.5
21	9.10697	98	9.11056	100	0.88944	9.99642	39	99 98
22	9.10795	98	9.11155	99	0.88845	9.99640	38	6 9.9 9.8
23	9.10893	98	9.11254	99	0.88746	9.99638	37	7 11.6 11.4
24	9.10990	97	9.11353	99	0.88647	9.99637	36	8 13.2 13.1
25	9.11087	97	9.11452	99	0.88548	9.99635	35	9 14.9 14.7
26	9.11184	97	9.11551	99	0.88449	9.99633	34	10 16.5 16.3
27	9.11281	97	9.11649	98	0.88351	9.99632	33	20 33.0 32.7
28	9.11377	96	9.11747	98	0.88253	9.99630	32	30 49.5 49.0
29	9.11474	97	9.11845	98	0.88155	9.99629	31	40 66.0 65.3
		96		98				50 82.5 81.7
30	9.11570	96	9.11943	97	0.88057	9.99627	30	
31	9.11666	95	9.12040	98	0.87960	9.99625	29	97 98 95
32	9.11761	96	9.12138	97	0.87862	9.99624	28	6 9.7 9.6 9.5
33	9.11857	95	9.12235	97	0.87765	9.99622	27	7 11.3 11.2 11.1
34	9.11952	95	9.12332	96	0.87668	9.99620	26	8 12.9 12.8 12.7 9 14.6 14.4 14.3
35	9.12047	95	9.12428	97	0.87572	9.99618	25	
36	9.12142	94	9.12525	96	0.87475	9.99617	24	10 16.2 16.0 15.8
37	9.12236	95	9.12621	96	0.87379	9.99615	23	20 32.3 32.0 31.7 30 48.5 48.0 47.5
38	9.12331	94	9.12717	96	0.87283	9.99613	22	
39	9.12425	94.	9.12813	96	0.87187	9.99612	21	40 64.7 64.0 63.3 50 80.8 80.0 79.2
40	9.12519		9.12909		0.87091	9.99610	20	50 50.5 50.0 79.2
41	9.12612	93	9.13004	95	0.86996	9.99608	19	94 93 92
42	9.12706	94	9.13099	95	0.86901	9.99607	18	6 9.4 9.3 9.2
43	9.12799	93	9.13194	95	0.86806	9.99605	17	7 11.0 10.9 10.7
44	9.12892	93	9.13289	95	0.86711	9.99603	16	8 12.5 12.4 12.3
45	9.12985	93	9.13384	95	0.86616	9.99601	15	9 14.1 14.0 13.8
46	9.13078	93	9.13478	94	0.86522	9.99600	14	10 15.7 15.5 15.3
47	9.13171	93	9.13573	95	0.86427	9.99598	13	20 31.3 31.0 30.7
48	9.13263	92	9.13667	94	0.86333	9.99596	12	30 47.0 46.5 46.0
49	9.13355	92	9.13761	94	0.86239	9.99595	iĩ	40 62.7 62.0 61.3
50	9.13447	92	9.13854	93	0.86146	9.99593		50 78.3 77.5 76.7
50 51	9.13539	92	9.13948	94	0.86052	9.99593	10	
52	9.13630	91	9.14041	93	0.85959	9.99591		91 90 2
53	9.13722	92	9.14134	93	0.85866	9.99588	8 7	6 9.1 9.0 0.2
54	9.13813	91	9.14227	93	0.85773	9.99586	6	7 10.6 10.5 0.2
		91		93				8 12.1 12.0 0.3
55	9.13904	90	9.14320	92	0.85680	9.99584	5	9 13.7 13.5 0.3
56	9.13994	91	9.14412	92	0.85588	9.99582	4	10 15.2 15.0 0.3
57	9.14085	90	9.14504	93	0.85496	9.99581	3	20 30.3 30.0 0.7
58	9.14175	91	9.14597	91	0.85403	9.99579	2	30 45.5 45.0 1.0
_59	9.14266	90	9.14688	92	0.85312	9.99577	_1	40 60.7 60.0 1.3
60	9.14356		9.14780	~~	0.8522C	9.99575	0	50 75.8 ; 75.0 1.7
	L. Cos.	d.	L. Cotg.	d. c.	L.Tang.	L. Sin.	,	P. P.
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1	L. Sin.	d.	L.Tang.	d. c.	L. Cotg.	L. Cos.		P. P.
0	9.14356	89	9.14780	92	0.85220	9.99575	60	92 91 90
$\begin{vmatrix} 1 \\ 2 \end{vmatrix}$	9.14445 9.14535	90	9.14872 9.14963	91	0.85128 0.85037	9.99574 9.99572	59 58	6 9.2 9.1 9.0
3	9.14624	89	9.15054	91	0.84946	9.99570	57	7 10.7 10.6 10.5 8 12.3 12.1 12.0
4	9.14714	90 89	9.15145	91 91	0.84855	9.99568	56	9 13.8 13.7 13.5
5 6	9,14803	88	9.15236 9.15327	91	0.84764 0.84673	9.99566 9.99565	55 54	10 15.3 15.2 15.0
1 7	9.14891 9.14980	89	9.15527	90	0.84583	9.99563	53	20 30.7 80.3 30.0 30 46.0 45.5 45.0
8	9.15069	89 88	9.15508	91 90	0.84492	9.99561	52	40 61.3 60.7 60.0
j_9	9.15157	88	9.15598	90	0.84402	9.99559	51	50 76.7 75.8 75.0
10	9.15245 9.15333	88	9.15688 9.15777	89	0.84312 0.84223	9.99557 9.99556	50 49	89 88
12	6.15421	88 87	9.15867	90 89	0.84133	9.99554	48	6 8.9 8.8 7 10.4 10.3
13 14	9.15508 9.15596	88	9.15956 9.16046	90	0.84044	9.99552 9.99550	47 46	8 11.9 11.7
15	9.15683	-87	9.16135	89	0.83865	9.99548	45	9 13.4 13.2
16	9.15770	87	9.16224	89	0.83776	9.99546	44	10 14.8 14.7 20 29.7 29.3
17	9.15857	87 87	9.16312	88 89	0.83688	9.99545	43	30 44.5 44.0
18 19	9.15944 9.16030	86	9.16401 9.16489	88	0.83599 0.83511	9.99543 9.99541	42 41	40 59.3 58.7 50 74.2 73.3
20	9.16116	86	9.16577	88	0.83423	9.99539	40	50 74.2 73.3
21	9.16203	87 86	9.16665	88 88	0.83335	9.99537	39	87 86
22 23	9.16289 9.16374	85	9.16753 9.16841	88 88	0.83247 0.83159	9.99535 9.99533	38 37	6 8.7 8.6 7 10.2 10.0
24	9.16460	86	9.16928	87	0.83072	9.99532	36	8 11.6 11.5
25	9.16545	85	9.17016	88	0.82984	9.99530	35	9 13.1 12.9 10 14.5 14.3
26 27	9.16631	86 85	9.17103	87 87	0.82897	9.99528	34 33	20 29.0 28.7
28	9.16716 9.16801	85	9.17190 9.17277	87	0.82810 0.82723	9.99526 9.99524	32	30 43.5 43.0
29	9.16886	85 84	9.17363	86	0.82637	9.99522	31	40 58.0 57.3 50 72.5 71.7
30	9.16970	85	9.17450	87 86	0.82550	9.99520	30	
31 32	9.17055 9.17139	84	9.17536 9.17622	86	0.82464 0.82378	9.99518 9.99517	29 28	85 84 6 8.5 8.4
33	9.17223	84	9.17708	86	0.82292	9.99515	27	7 9.9 9.8
34	9.17307	84 84	9.17794	86 86	0.82206	9.99513	26	8 11.3 11.2 9 12.8 12.6
35 36	9.17391 9.17474	83	9.17880 9.17965	85	0.82120 0.82035	9.99511 9.99509	25 24	10 14.2 14.0
37	9.17558	84	9.18051	86	0.81949	9.99507	23	20 28.3 28.0
38	9.17641	83 83	9.18136	85 85	0.81864	9.99505	22	30 42.5 42.0 40 56.7 56.0
39	$\frac{9.17724}{9.17807}$	83	9.18221	85	0.81779	9.99503	21 20	50 70.8 70.0
40 41	9.17890	83	9.18391	85	0.81694	9.99501	19	83 82
42	9.17973	83 82	9.18475	84	0.81525	9.99497	18	6 8.3 8.2
43 44	9.18055 9.18137	82	9.18560 9.18644	85 84	0.81440 0.81356	9.99495 9.99494	17 16	7 9.7 9.6
45	9.18137	83	9.18728	84	0.81350	9.99492	15	8 11.1 10.9 9 12.5 12.3
46	9.18302	82	9.18812	84	0.81188	9.99490	14	10 13.8 13.7
47	9.18383	81 82	9.18896	84 83	0.81104	9.99488 9.99486	13	20 27.7 27.3 30 41.5 41.0
48 49	9.18465 9.18547	82	9.18979 9.19063	84	0.81021 0.80937	9.99486	12 11	40 55.3 54.7
50	9.18628	81	9.19146	83	0.80854	9.99482	10	50 69.2 68.3
51	9.18709	81 81	9.19229	83 83	0.80771	9.99480	9	81 80 2
52 53	9.18790 9.18871	81	9.19312 9.19395	83	0.80688	9.99478 9.99476	8	6 8.1 8.0 0.2
54	9.18952	81	9.19478	83	0.80522	9.99474	6	7 9.5 9.3 0.2 8 10.8 10.7 0.3
55	9.19033	81	9.19561	83	0.80439	9.99472	5	9 12.2 12.0 0.3
56 57	9.19113 9.19193	80 80	9.19643 9.19725	82 82	0.80357 0.80275	9.99470 9.99468	3	10 13.5 13.3 0.3 20 27.0 26.7 0.7
58	9.19193	80	9.19725	82	0.80275	9.99468	2	30 40.5 40.0 1.0
59	9.19353	80 80	9.19889	82 82	0.80111	9.99464	ī	40 54.0 53.3 1.3
60	9.19433		9.19971	02	0.80029	9.99462	0	50 67.5 66.7 1.7
	L. Cos.	d.	L. Cotg.	d. c.	L.Tang.	L. Sin.		P. P.

	' 1	L	Sin.	d.	L.Tang.	d. c.	L. Cotg.	L. Cos.		P. P.
	0		.19433		9.19971	~~	0.80029	9.99462	60	82 81 80
	1		1 9513	80 79	9.20053	82 81	0.79947	9.99460	59	6 8.2 8.1 8.0
	3	ă	1.9592	80	9.20134	82	0.79866	9.99458	58	7 9.6 9.5 9.3
	4	lä	19672 19751	79	9.20216 9.20297	81	0.79784 0.79703	9.99456 9.99454	57 56	8 10.9 10.8 10.7
l-		_		79	9.20237	81	0.79622	9.99452	55	9 12.3 12.2 12.0
ı	5		€.19830 9.19909	79	9.20459	81	0.79541	9.99450	54	10 13.7 13.5 13.3
l	6 7		9.19988	79	9.20540	81	0.79460	9.99448	53	20 27.3 27.0 26.7 30 41.0 40.5 40.0
ı	8		9.20067	79	9.20621	81	0.79379	9.99446	52	40 54.7 54.0 53.3
١	9		9.20145	78	9.20701	80	0.79299	9.99444	51	50 68.3 67.5 66.7
١	10	-1	9.20223	78	9.20782	81	0.79218	9.99442	50	
١	11	1	9.20302	79	9.20862	80	0.79138	9.99440	49	7 9 78 6 7.9 7.8
1	12		9.20380	78 78	9.20942	80 80	0.79058	9.99438	48	$\begin{array}{c cccc} 6 & 7.9 & 7.8 \\ 7 & 9.2 & 9.1 \end{array}$
1	13 14		9.20458 9.20535	77	9.21022 9.21102	80	0.78978 0.78898	9.99436 9.99434	47 46	8 10.5 10.4
-		_		78		80				9 11.9 11.7
	15 16		9.20613 9.20691	78	9.21182 9.21261	79	0.78818 0.78739	9.99432 9.99429	45 44	10 13.2 13.0
	1 13		9.20768	77	9.21341	80	0.78659	9.99427	48	20 26.3 26.0
	lii		9.20845	77	9.21420	79	0.78580	9.99425	42	30 39.5 39.0 40 52.7 52.0
	1 19		9.20922	77	9.21499	79	0.78501	9.99423	41	50 65.8 65.0
	120		9.20999	77	9.21578	79	0.78422	9.99421	40	,,
	2	1	9.21076	77	9.21657	79	0.78343	9.99419	39	77 76
		2	9.21153	77 76	9.21736	79 78	0.78264	9.99417	38	6 7.7 7.6
		3	9.21229	77	9.21814	78	0.78186	9.99415	37	7 9.0 8.9 8 10.3 10.1
	1 -	4	9.21306	76	9.21893	78	0.78107	9.99413	36	8 10.3 10.1 9 11.6 11.4
		≥5	9.21382	76	9.21971	78	0.78029	9.99411	35	10 12.8 12.7
	13	26 27	9.21458 9.21534	76	9.22049 9.22127	78	0.77951 0.77873	9.99409 9.99407	34 33	20 25.7 25.3
	1 :	26 28	9.21610	76	9.22205	78	0.77795	9.99404	32	30 38.5 38.0
		29 l	9.21685	75	9.22283	78	0.77717	9.99402	31	40 51.3 50.7
		30	9.21761	76	9.22361	78	0.77639	9.99400	30	50 64.2 63.3
		3ĭ	9.21836	75	9.22438	77	0.77562	9.99398	29	75 74
		32	9.21912	76	9.22516	78	0.77484	9.99396	28	6 7.5 7.4
		33	9.21987	75 75	9.22593	77 77	0.77407	9.99394	27	7 8.8 8.6
	1	34	9.22062	75	9.22670	77	0.77330	9.99392	26	8 10.0 9.9
		35	9.22137	74	9.22747	77	0.77253	9.99390	25	9 11.3 11.1 10 12.5 12.3
		36	9.22211	75	9.22824	77	0.77176	9.99388	24	20 25.0 24.7
		37 38	9.22286 9.22361	75	9.22901 9.22977	76	0.77099 0.77023	9.99385 9.99383	23 22	30 37.5 37.0
		39	9.22435	74	9.23054	77	0.76946	9.99381	21	40 50.0 49.3
	- I	10	9.22509	74	9.23130	76	0.76870	9.99379	20	50 62.5 61.7
		41	9.22583	74	9.23206	76	0.76794	9.99377	19	73 72
		42	9.22657	74	9.23283	77	0.76717	9.99375	18	6 7.3 7.2
	- 1	43	9.22731	74	9.23359	76	0.76641	9.99372	17	7 8.5 8.4
	- 1	44	9.22805	74 73	9.23435	76 75	0.76565	9.99370	16	8 9.7 9.6
		45	9.22878		9.23510		0.76490	9.99368	15	9 11.0 10.8
		46	9.22952	74 73	9.23586	76 75	0.76414	9.99366	14	10 12.2 12.0 20 24.3 24.0
		47	9.23025 9.23098	73	9.23661 9.23737	76	0.76339	9.99364	13	20 24.3 24.0 30 36.5 36.0
		48 49	9.23098	73	9.23737	75	0.76263 0.76188	9.99362 9.99359	12 11	40 48.7 48.0
	-	50	9.23244	73	9.23887	75	0.76113	9.99357		50 60.8 60.0
		50 51	9.23244	73	9.23962	75	0.76113	9.99355	10	' '
		52	9.23390	73	9.24037	75	0.75963	9.99353	8	$\begin{array}{c c c c} 71 & 3 & 2 \\ 6 & 7.1 & 0.3 & 0.2 \end{array}$
	- 1	53	9.23462	72	9.24112	75	0.75888	9.99351	7	6 7.1 0.3 0.2 7 8.3 0.4 0.2
		54	9.23535	73 72	9.24186	74 75	0.75814	9.99348	6	8 9.5 0.4 0.3
	- 1	55	9.23607		9.24261		0.75739	9.99346	- 5	9 10.7 0.5 0.3
		56	9.23679	72 73	9.24335	74 75	0.75665	9.99344	4	10 11.8 0.5 0.3
		57	9.23752	71	9.24410	75 74	0.75590	9.99342	3	20 23.7 1.0 0.7
		58 59	9.23823 9.23895	72	9.24484 9.24558	74	0.75516 0.75442	9.99340 9.99337	2	30 35.5 1.5 1.0 40 47.3 2.0 1.3
				72		74				50 59.2 2.5 1.7
	- 1	60	9.23967		9.24632		0.75368	9.99335	0	
	Ĺ		L. Cos.	d.	L. Cotg.	d. c.	L.Tang.	L. Sin.	<u> </u>	P. P.
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,	L. Sin.	d.	L.Tang.	d. c.	L. Cotg.	L. Cos.		P. P.
0	9.23967		9.24632		0.75368	9.99335	60	
1	9.24039	72	9.24706	74	0.75294	9.99333	59	74 73 6 7.4 7.3
2	9.24110	71 71	9.24779	73 74	0.75221	9.99331	58	7 8.6 8.5
3	9.24181	72	9.24853	73	0.75147	9.99328	57	8 9.9 9.7
4	9.24253	71	9.24926	74	0.75074	9.99326	56	9 11.1 11.0
5	9.24324	71	9.25000	73	0.75000	9.99324	55	10 12.3 12.2
6	9.24395	71	9,25073	73	0.74927	9.99322	54	20 24.7 24.3
7	9.24466	70	9.25146	73	0.74854	9.99319	53	30 37.0 36.5
8	9.24536 9.24607	71	9.25219 9.25292	73	0.74781 0.74708	9.99317	52	40 49.3 48.7
		70		73		9.99315	51	50 61.7 60.8
10	9.24677	71	9.25365	72	0.74635	9.99313	50	72 71
11 12	9.24748 9.24818	70	9.25437 9.25510	73	0.74563 0.74490	9.99310 9.99308	49	6 7.2 7.1
13	9.24888	70	9.25582	72	0.74418	9.99306	47	7 8.4 8.3
14	9.24958	70	9.25655	73	0.74345	9.99304	46	8 9.6 9.5
15	9.25028	70	9.25727	72	0.74273	9.99301	45	9 10.8 10.7
16	9.25028	70	9.25799	72	0.74273	9.99299	44	10 12.0 11.8
17	9.25168	70	9.25871	72	0.74129	9.99297	43	20 24.0 23.7
18	9.25237	69	9.25943	72	0.74057	9.99294	42	30 36.0 35.5
19	9.25307	70	9.26015	72	0.73985	9.99292	41	40 48.0 47.3 50 60.0 59.2
20	9.25376	69	9.26086	71	0.73914	9.99290	40	30 60.0 59.2
21	9.25445	69	9.26158	72	0.73842	9.99288	39	70 69
22	9.25514	69	9.26229	71	0.73771	9.99285	38	6 7.0 6.9
23	9.25583	69	9.26301	72	0.73699	9.99283	37	7 8.2 8.1
24	9.25652	69	9.26372	71	0.73628	9.99281	36	8 9.3 9.2
25	9.25721	69	9.26443	71	0.73557	9.99278	35	9 10.5 10.4
26	9.25790	69	9.26514	71	0.73486	9.99276	34	10 11.7 11.5 20 23.3 23.0
27	9.25858	68	9.26585	71	0.73415	9.99274	33	20 23.3 23.0 30 35.0 34.5
28	9.25927	69 68	9.26655	70	0.73345	9.99271	32	40 46.7 46.0
29	9.25995	68	9.26726	71 71	0.73274	9.99269	31	50 58.3 57.5
30	9.26063		9.26797	1	0.73203	9.99267	30	00 00.0 01.0
31	9.26131	68 68	9.26867	70 70	0.73133	9.99264	29	68 67
32	9.26199	68	9.26937	71	0.73063	9.99262	28	6 6.8 6.7
33	9.26267	68	9.27008	70	0.72992	9.99260	27	7 7.9 7.8
34	9.26335	68	9.27078	70	0.72922	9.99257	26	8 9.1 8.9 9 10.2 10.1
35	9.26403	67	9.27148	70	0.72852	9.99255	25	10 11.3 11.2
36	9.26470	68	9.27218	70	$0.72782 \\ 0.72712$	9.99252	24 23	20 22.7 22.3
37 38	9.26538 9.26605	67	9.27288	69	0.72712	9.99250 9.99248	22	30 34.0 33.5
39	9.26672	67	9.27427	70	0.72573	9.99245	21	40 45.3 44.7
		67		69			20	50 56.7 55.8
40 41	9.26739 9.26806	67	9,27496 9,27566	70	0.72504 0.72434	9.99243 9.99241	19	
42	9.26873	67	9.27635	69	0.72365	9.99238	18	66 65
43	9.26940	67	9.27704	69	0.72296	9.99236	17	7 7.7 7.6
44	9.27007	67	9.27773	69	0.72227	9.99233	16	8 8.8 8.7
45	9.27073	66	9.27842	69	0.72158	9.99231	15	9 9.9 9.8
46	9.27140	67	9.27911	69	0.72089	9.99229	14	10 11.0 10.8
47	9.27206	66	9.27980	69	0.72020	9.99226	13	20 22.0 21.7
48	9.27273	67	9.28049	69	0.71951	9.99224	12	30 33.0 32.5
49	9.27339	66 66	9.28117	68	0.71883	9.99221	11	40 44.0 43.3
50	9.27405		9.28186	69	0.71814	9.99219	10	50 55.0 54.2
51	9.27471	66	9.28254	68	0.71746	9.99217	9	3 2
52	9.27537	66 65	9.28323	69 68	0.71677	9.99214	8	6 0.3 0.2
53	9.27602	66	9.28391	68	0.71609	9.99212	7	7 0.4 0.2
54	9.27668	66	9.28459	68	0.71541	9.99209	6	8 0.4 0.3
55	9.27734		9.28527	68	0.71473	9.99207	5	9 0.5 0.3
56	9.27799	65 65	9.28595	67	0.71405	9.99204	4	10 0.5 0.3
57	9.27864	66	9.28662	68	0.71338	9.99202	3	10 1.0 0.7
58 59	9.27930 9.27995	65	9.28730	68	0.71270	9.99200	2	30 1.5 1.0 40 2.0 1.3
		65	9.28798	67	0.71202	9.99197		40 2.0 1.3 50 2.5 1.7
60	9.28060		9.28865		0.71135	9.99195	0	
	L. Cos.	d.	L. Cotg.	d. c.	L.Tang.	L. Sin.	/	P. P.
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7	L. Sin.	d	L.Tang.	d. c.	L. Cotg.	L. Cos.		P. P.
0	9.28060	CE.	9.28865	60	0.71135	9.99195	60	68 67
1	9.28125	65 65	9.28933	68 67	0.71067	9.99192	59	6 6.8 6.7
2 3	9.28190 9.28254	64	9.29000 9.29067	67	0.71000 0.70933	9.99190 9.99187	58 57	7 7.9 7.8
4	9.28319	65	9.29134	67	0.70866	9.99185	56	8 9.1 8.9
5	9.28384	65	9.29201	67	0.70799	9.99182	55	9 10.2 10.1 10 11.3 11.2
6	9.28448	64 64	9.29268	67 67	0.70732	9.99180	54	20 22.7 22.3
7	9.28512	65	9.29335	67	0.70665	9.99177	53	30 34.0 33.5
8	9.28577 9.28641	64	9.29402 9.29468	66	0.70598 0.70532	9.99175 9.99172	52 51	40 45.3 44.7 50 56.7 55.8
10	9.28705	64	9.29535	67	0.70465	9.99170	50	50 56.7 55.8
ii	9.28769	64	9.29601	66	0.70399	9.99167	49	66 65
12	9.28833	64 63	9.29668	67 66	0.70332	9.99165	48	$\begin{array}{c c c} 6 & 6.6 & 6.5 \\ 7 & 7.7 & 7.6 \end{array}$
13 14	9.28896 9.28960	64	9.29734 9.29800	66	0.70266	9.99162	47	8 8.8 8.7
15		64	9.29866	66	0.70200	9.99160	46	9 9.9 9.8
16	9.29024 9.29087	63	9.29800	66	0.70134	9.99157 9.99155	45 44	10 11.0 10.8
17	9.29150	63	9.29998	66	0.70002	9.99152	43	20 22.0 21.7 30 33.0 32.5
18	9.29214	64 63	9.30064	66 66	0.69936	9.99150	42	40 44.0 43.3
19	9.29277	63	9.30130	65	0.69870	9.99147	41	50 55.0 54.2
20	9.29340	63	9.30195	66	0.69805	9.99145	40	64 63
21 22	9.29403 9.29466	63	9.30261 9.30326	65	0.69739	9.99142 9.99140	39 38	6 64 63
23	9.29529	63	9.30391	65	0.69609	9.99137	37	7 7.5 7.4
24	9.29591	62 63	9.30457	66 65	0.69543	9.99135	36	8 8.5 8.4
25	9.29654	62	9.30522	65	0.69478	9.99132	35	9 9.6 9.5 10 10.7 10.5
26	9.29716	63	9.30587	65	0.69413	9.99130	34	20 21.3 21.0
27 28	9.29779 9.29841	62	9.30652 9.30717	65	0.69348 0.69283	9.99127 9.99124	33 32	30 32.0 31.5
29	9.29903	62	9.30782	65	0.69218	9.99122	31	40 42.7 42.0
30	9.29966	63	9.30846	64	0.69154	9.99119	30	50 53.3 52.5
31	9.30028	62 62	9.30911	65 64	0.69089	9.99117	29	62 61
32		61	9.30975 9.31040	65	0.69025 0.68960	9.99114 9.99112	28 27	$egin{array}{ c c c c c c c c c c c c c c c c c c c$
34		62	9.31104	64	0.68896	9.99109	26	7 7.2 7.1 8 8.3 8.1
35		62	9.31168	64	0.68832	9.99106	25	9 9.3 9.2
36		61	9.31233	65	0.68767	9.99104	24	10 10.3 10.2
37	9.30398	62 61	9.31297	64 64	0.68703	9.99101	23	20 20.7 20.3 30 31.0 30.5
38		62	9.31361 9.31425	64	0.68639 0.68575	9.99099 9.99096	22 21	40 41.3 40.7
40		61	9.31489	64	0.68511	9.99093	20	50 51.7 50.8
41		61	9.31552	63	0.68448	9.99091	19	80 59
42	9.30704	61	9.31616	64 63	0.68384	9.99088	18	6 6.0 5.9
43		61	9.31679	64	0.68321	9.99086 9.99083	17 16	7 7.0 6.9
		61	9.31743	63		9.99080		8 8.0 7.9 9 9.0 8.9
45 46		60	9.31806 9.31870	64	0.68194 0.68130	9.99080	15 14	10 10.0 9.8
47		61	9.31933	63	0.68067	9.99075	13	20 20.0 19.7
48		60 61	9.31996	63 63	0.68004	9.99072	12	30 30.0 29.5
49		60	9.32059	63	0.67941	9.99070	11	40 40.0 39.3 50 50.0 49.2
50		61	9,32122	63	0.67878	9.99067	10	l ' '
51 52		60	9.32185 9.32248	63	0.67815 0.67752	9.99064 9.99062	9 8	3 2
59	9.31370	60	9.32311	63	0.67689	9.99059	7	$egin{array}{c c c} 6 & 0.3 & 0.2 \\ 7 & 0.4 & 0.2 \\ \hline \end{array}$
54	-	60	9.32373	62 63	0.67627	9.99056	6	8 0.4 0.3
55		59	9.32436	62	0.67564	9.99054	5	9 0.5 0.3
50		60	9.32498 9.32561	63	0.67502 0.67439	9.99051 9.99048	3	10 0.5 0.3 20 1.0 0.7
5		60	9.32623	62	0.67377	9.99046	2	30 1.5 1.0
5		59	9.32685	62 62	0.67315	9.99043	ĩ	40 2.0 1.3
60	9.31788	60	9.32747	02	0.67253	9.99040	0	50 2.5 1.7
	L. Cos.	d.	L. Cotg.	d. c.	L.Tang.	L. Sin.	,-	P. P.

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	L. Sin.	d.	L.Tang.	d. c.	L. Cotg.	L. Cos.	ı	. P. P.
0	9.31788	59	9.32747	63	0.67253	9.99040	60	63 62
1	9.31847	60	9.32810	62	0.67190	9.99038	59	6 6.3 6.2
$\frac{2}{3}$	9.31907 9.31966	59	9.32872 9.32933	61	0.67128	9.99035 9.99032	58 57	7 7.4 7.2
4	9.32025	59	9.32995	62	0.67005	9.99030	56	8 8.4 8.3
5	9.32084	59	9.33057	62	0.66943	9.99027	55	9 9.5 9.3 1 10 10.5 10.3
ŏ l	9.32143	59	9.33119	62	0.66881	9.99024	54	20 21.0 20.7
7	9.32202	59 59	9.33180	61 62	0.66820	9.99022	53	30 31.5 31.0
8 9	9.32261 9.32319	58	9.33242 9.33303	61	0.66758 0.66697	9.99019 9.99016	52	40 42.0 41.3
		59		62			51	50 52.5 51.7
10 11	9.32378 9.32437	59	9.33365 9.33426	61	0.66635 0.66574	9.99013 9.99011	50 49	61 80 3
12	9.32495	58	9.33487	61	0.66513	9.99008	48	6 6.1 6.0
13	9.32553	58	9.33548	61	0.66452	9.99005	47	7 7.1 7.0
14	9.32612	59 58	9.33609	61 61	0.66391	9.99002	46	8 8.1 8.0 9 9.2 9.0
15	9.32670	58	9.33670	61	0.66330	9.99000	45	10 10.2 10.0
16	9.32728 9.32786	58	9.33731	61	0.66269	9.98997	44	20 20.3 20.0
17 18	9.32844	58	9.33792 9.33853	61	0.66208 0.66147	9.98994 9.98991	43 42	30 30.5 30.0
19	9.32902	58	9.33913	60	0.66087	9.98989	41	40 40.7 40.0 50 50.8 50.0
20	9.32960	58	9.33974	61	0.66026	9.98986	40	50 50.8 50.0
21	9.33018	58	9.34034	60	0.65966	9.98983	39	59
22	9.33075	57 58	9.34095	61 60	0.65905	9.98980	38	6 5.9
23	9.33133	57	9.34155	60	0.65845	9.98978	37	7 6.9 8 7.9
24	9.33190	58	9.34215	61	0.65785	9.98975	36	- 9 8.9
25 26	9.33248 9.33305	57	9.34276 9.34336	60	0.65724 0.65664	9.98972 9.98969	35 34	10 9.8
27	9.33362	57	9.34396	60	0.65604	9.98967	33	20 19.7
28	9.33420	58	9.34456	60	0.65544	9.98964	32	30 29.5
29	9.33477	57 57	9.34516	60 60	0.65484	9.98961	31	40 39.3 50 49.2
30	9.33534		9.34576	59	0.65424	9.98958	30	00 40.2
31	9.33591	57 56	9.34635	60	0.65365	9.98955	29	58 57
32 33	9.33647 9.33704	57	9.34695 9.34755	60	0.65305 0.65245	9.98953 9.98950	28 27	6 5.8 5.7 7 6.8 6.7
34	9.33761	57	9.34814	59	0.65186	9.98947	26	7 6.8 6.7 8 7.7 7.6
35	9.33818	57	9,34874	60	0.65126	9.98944	25	9 8.7 8.6
36	9.33874	56	9.34933	59	0.65067	9.98941	24	10 9.7 9.5
37	9.33931	57 56	9.34992	59 59	0.65008	9.98938	23	20 19.3 19.0 30 29.0 28.5
38	9.33987	56	9.35051	60	0.64949	9,98936	22	30 29.0 28.5 40 38.7 38.0
39	9.34043	57	9.35111	59	0.64889	9.98933	21	50 48.3 47.5
40 41	9.34100 9.34156	56	9.35170 9.35229	59	0.64830 0.64771	9.98930 9.98927	20 19	1 ' '
42	9.34212	56	9.35288	59	0.64712	9.98924	18	58 55 6 5.6 5.5
43	9.34268	56	9.35347	59	0.64653	9.98921	17	7 6.5 6.4
44	9.34324	56 56	9.35405	58 59	0.64595	9.98919	16	8 7.5 7.3
45	9.34380	56	9.35464	59	0.64536	9.98916	15	9 8.4 8.3
46 47	9.34436 9.34491	55	9.35523	58	0.64477 0.64419	9.98913 9.98910	14 13	10 9.3 9.2 20 18.7 18.3
48	9.34547	56	9.35581 9.35640	59	0.64360	9.98910	13	30 28.0 27.5
49	9.34602	55	9.35698	58	0.64302	9.98904	ii	40 37.3 36.7
50	9.34658	5 6	9.35757	59	0.64243	9.98901	10	50 46.7 45.8
51	9.34713	55	9.35815	58	0.64185	9.98898	9	3 2
52	9.34769	56 55	9.35873	58 58	0.64127	9.98896	8	6 0.3 0.2
$\frac{53}{54}$	9.34824 9.34879	55 55	9.35931 9.35989	58	0.64069	9.98893	7	7 0.4 0.2
11 8 12 801	~~~	55		58	0.64011	9.98890		8 0.4 0.3
55 ; 56	9.34934 9.34989	55	9.36047 9.36105	58	0.63953 0.63895	9.98887 9.98884	5 4	9 0.5 0.3
57	9.35044	55	9.36163	58	0.63837	9.98881	3	20 1.0 0.3
58	9.35099	55 55	9.36221	58	0.63779	9.98878	2	30 1.5 1.0
59	9.35154	55	9.36279	58 57	0.63721	9.98875	1	40 2.0 1.3
60	9.35209		9.36336		0.63664	9.98872	0	50 2.5 1.7
	L. Cos.	d.	L. Cotg.	d. c.	L.Tang.	L. Sin.	′	P. P.

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1	L. Sin.	d.	L.Tang.	d. c.	L. Cotg.	L. Cos.		P. P.
0	9.35209		9.36336		0.63664	9.98872	60	
ĭ	9.35263	54	9.36394	58	0.63606	9.98869	59	58 57
2	9.35318	55	9.36452	58	0.63548	9.98867	58	6 5.8 5.7
3	9.35373	55	9.36509	57	0.63491	9.98864	57	7 6.8 6.7
4	9.35427	54	9.36566	57	0.63434	9.98861	56	8 7.7 7.6
		54		58				9 8.7 8.6
5	9.35481	55	9.36624		0.63376	9.98858	55	10 9.7 9.5
6	9.35536		9.36681	57	0.63319	9.98855	54	20 19.3 19.0
7	9.35590	54	9.36738	57	0.63262	9.98852	53	30 29.0 28.5
8	9.35644	54	9.36795	57	0.63205	9.98849	52	40 38.7 38.0
9	9.35698	54	9.36852	57	0.63148	9.98846	51	50 48.3 47.5
0	9.35752	54	9.36909	57	0.63091	9.98843	50	00 1010 1110
1	9.35806	54	9.36966	57	0.63034	9.98840	49	56 55
2	9.35860	54	9.37023	57	0.62977	9.98837	48	6 5.6 5.5
3	9.35914	54	9.37080	57	0.62920	9.98834	47	7 6.5 6.4
4	9.35968	54	9.37137	57		9.98831	46	8 7.5 7.3
		54		56	0.62863			9 8.4 8.3
5	9.36022	53	9.37193		0.62807	9.98828	45	10 9.3 9.2
.6	9.36075		9.37250	57	0.62750	9.98825	44	20 18.7 18.3
.7	9.36129	54	9.37306	56	0.62694	9.98822	43	30 28.0 27.5
.8	9.36182	53	9.37363	57	0.62637	9.98819	42	40 37.3 36.7
.9	9.36236	54	9.37419	56	0.62581	9.98816	41	
0	9.36289	53	9.37476	57	0.62524	9.98813	40	50 46.7 45.8
1	9.36342	53	9.37532	56		9.98810	39	54
2	9.36395	53		56	0.62468		38	6 5.4
-Z		54	9.37588	56	0.62412	9.98807		
3	9.36449	53	9.37644	56	0.62356	9.98804	37	
:4	9.36502	53	9.37700	56	0.62300	9.98801	36	8 7.2
5	9.36555		9.37756		0.62244	9.98798	35	9 8.1
:6	9.36608	53	9.37812	56	0.62188	9.98795	34	10 9.0
:7	9.36660	52	9.37868	56	0.62132	9.98792	33	20 18.0
28	9.36713	53	9.37924	56	0.62076	9.98789	32	30 27.0
<u>19</u>	9.36766	53	9.37980	56	0.62020	9.98786	31	40 36.0
	9.36819	53		55				50 45.0
0		52	9.38035	56	0.61965	9.98783	30	
31	9.36871	53	9.38091	56	0.61909	9.98780	29	53 52
32	9.36924	52	9.38147	55	0.61853	9.98777	28	6 5.3 5.2
33	9.36976	52 52	9.38202	55	0.61798	9.98774	27	7 6.2 6.1
34	9.37028	53	9.38257	56	0.61743	9.98771	26	8 7.1 6.9
35	9.37081		9.38313		0.61687	9.98768	25	9 8.0 7.8
36	9.37133	52	9.38368	55	0.61632	9.98765	24	10 8.8 8.7
37	9.37185	52	9.38423	55	0.61577	9.98762	23	20 17.7 17.3
38	9.37237	52	9.38479	56	0.61521	9.98759	22	30 26.5 26.0
39	9.37289	52	9.38534	55	0.61466	9.98756	21	40 35.3 34.7
		52		55				50 44.2 43.3
0	9.37341	52	9.38589	55	0.61411	9.98753	20	,,
11	9.37393	52	9.38644	55	0.61356	9.98750	19	51 4
12	9.37445	52	9.38699		0.61301	9.98746	18	6 5.1 0.4
13	9.37497		9.38754	55	0.61246	9.98743	17	7 6.0 0.5
14	9.37549	52 51	9.38808	54	0.61192	9.98740	16	8 6.8 0.5
15	9.37600	51	9.38863	55	0.61137	9.98737	15	9 7.7 0.6
16	9.37652	52	9.38918	55	0.61082	9.98734	14	10 8.5 0.7
17	9.37703	51	9.38972	54	0.61028	9.98731	13	20 17.0 1.3
48	9.37755	52	9.39027	55	0.60973	9.98728	12	30 25.5 2.0
49	9.37806	51	9.39082	55	0.60918	9.98725	11	40 34.0 2.7
		52		54				50 42.5 3.3
j0	9.37858	51	9.39136	54	0.60864	9.98722	10.	30,12.0,0.0
51	9.37909	51	9.39190	55	0.60810	9.98719	9	3 2
52	9.37960	51	9.39245	54	0.60755	9.98715	8	6 0.3 0.2
53	9.38011		9.39299		0.60701	9.98712	7	7 0.4 0.2
54	9.38062	51 51	9.39353	54	0.60647	9.98709	6	8 0.4 0.3
55	9.38113		9.39407	54	0.60593	9.98706	5	9 0.5 0.3
56	9.38164	51	9.39461	54	0.60539	9.98703	4	10 0.5 0.3
57	9.38215	51	9.39515	54	0.60485	9.98700	3	20 1.0 0.3
58	9.38266	51	9.39569	54	0.60431	9.98697	2	30 1.5 1.0
59	9.38317	51	9.39623	54	0.60377		1	
		51		54		9.98694		
BO	9.38368		9.39677		0.60323	9.98690	0	50 2.5 1.7
	L. Cos.	<u>d.</u>	L. Cotg.	d. c.	L.Tang.	L. Sin.	1	P. P.
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0 1 2 3	L. Sin. 9.38368 9.38418 9.38469	d. 50	L.Tang.	d. c.	L. Cotg.	L. Cos.	d.	ı —	1	P. I	·
1 2	9.38418 9.38469	50						I	 		
l 2 i	9.38469		9.39677 9.39731	54	0.60323 0.60269	9.98690 9.98687	3	60 59			
		51 50	9.39785	54 53	0.60215	9.98684	3	58		54	. 6
	9.38519	51	9.39838	54	0.60162	9.98681	3	57	6	5.4	55
- 4 5	9.38570	50	9.89892	53	0.60108	9.98678	3	56	7	6.3	6
6	9.38670	50	9.39945 9.39999	54	0.60055 0.60001	9.98675 9.98671	4	55 54	8	7.2	7. 8. 8. 17.
7 1	9.38721	51	9.40052	53	0.59948	9.98668	3	53	9 10	8.1 9.0	1 8
8	9.38771	50 50	9.40106	54 53	0.59894	9.98665	3	52	20	18.0	17.
9	9.38821	50	9.40159	53	0.59841	9.98662	3	51	30	27.0	26, 35,
10	9.38871 9.38921	50	9.40212 9.40266	54	0.59788 0.59734	9.98659 9.98656	3	50 49	40 50	36.0 45.0	30
12	9.38971	50	9.40319	53	0.59681	9.98652	4	48		10.0	1 22
13	9.39021	50 50	9.40372	53	0.59628	9.98649	3	47			
14	9.39071	50	9.40425	53 53	0.59575	9.98646	3	46		52 5.2	1 5
15	9.39121	49	9.40478	53	0.59522	9.98643	3	45	6	5.2	5.
16 17	9.39170 9.39220	50	9.40531 9.40584	53	0.59469 0.59416	9.98640 9.98636	4	44 43	7 8	6.1 6.9	6.
18	9.39270	50	9.40636	52	0.59364	9.98633	3	42	9	7.8	7.
19	9.39319	49 50	9.40689	53 53	0.59311	9.98630	3	41	10	8.7	8.
20	9.39369	49	9.40742	53	0.59258	9.98627	4	40	20 30	17.3 26.0	17. 25.
21 22	9.39418 9.39467	49	9.40795 9.40847	52	0.59205 0.59153	9.98623 9.98620	3	39 38	40	34.7	34
23	9.39517	50	9.40900	53	0.59100	9.98617	3	37	50	43.3	42.
24	9.39566	49 49	9.40952	52 53	0.59048	9.98614	3 4	36			
25	9.39615	49	9.41005	52	0.58995	9.98610	3	35			
26 27	9.39664 9.39713	49	9.41057 9.41109	52	0.58943 0.58891	9.98607 9.98604	3	34 33	6	50 5.0	41
28	9.39762	49	9.41161	52	0.58839	9.98601	3	32	7	5.8	5.
29	9.39811	49 49	9.41214	53 52	0.58786	9.98597	4 3	31	8	6.7	6.
30	9.39860	49	9.41266	52	0.58734	9.98594	3	30	9 10	7.5 8.3	7. 8.
31 32	9.39909 9.39958	49	9.41318 9.41370	52	0.58682 0.58630	9.98591 9.98588	3	29 28	20	16.7	16.
33	9.40006	48	9.41422	52	0.58578	9.98584	4	27	30	25.0	24.
34	9.40055	49 48	9.41474	52 52	0.58526	9.98581	3	26	40 50	33.3 41.7	32. 40.
35	9.40103	49	9.41526	52	0.58474	9.98578	4	25	"		1 20.
36 37	9.40152 9.40200	48	9.41578 9.41629	51	0.58422 0.58371	9.98574 9.98571	3	24 23			
38	9.40249	49	9.41681	52	0.58319	9.98568	3	22		48	47
39	9.40297	48 49	9.41733	52 51	0.58267	9.98565	3 4	21	6	4.8	4.
40	9.40346	48	9.41784	52	0.58216	9.98561	3	20	8	5.6 6.4	5. 6.
41 42	9.40394 9.40442	48	9.41836 9.41887	51	0.58164 0.58113	9.98558 9.98555	3	19 18	9	7.2	7.
43	9.40490	48	9.41939	52	0.58061	9.98551	4	17	10 20	8.0	7.
44	9.40538	48 48	9.41990	51 51	0.58010	9.98548	3	16	30	16.0 24.0	15. 23.
45	9.40586	48	9.42041	52	0.57959	9.98545	4	15	40	32.0	31.3
46 47	9.40634 9.40682	48	9.42093 9.42144	51	0.57907 0.57856	9.98541 9.98538	3	14 13	50	40.0	39.
48	9.40082	48	9.42144	51	0.57805	9.98535	3 4	12			
49	9.40778	48 47	9.42246	51 51	0.57754	9.98531		iī			1 •
50	9.40825	48	9.42297	51 51	0.57703	9.98528	3	10	6	0.4	0.3
51 52	9.40873 9.40921	48	9.42348 9.42399	51	0.57652 0.57601	9.98525 9.98521	3 4	9	7	0.5	0.4
53	9.40921	47	9.42399	51	0.57550	9.98521	3	8	8 9		0.4
54	9.41016	48	9.42501	51	0.57499	9.98515	3 4	6	10	0.6	0.5
55	9.41063	47	9.42552	51	0.57448	9.98511	_	5	20	1.3	1.0
56 57	9.41111	48 47	9.42603	51 50	0.57397	9.98508	3	4	30	2.0 2.7	1.5
58	9.41158 9.41205	47	9.42653 9.42704	51	0.57347 0.57296	9.98505 9.98501	4	3 2	40 50	2.7 3.3	2.0
59	9.41252	47	9.42755	51	0.57245	9.98498	3	í	- 30	, 0.0	, 2.0
60	9.41300	48	9.42805	50	0.57195	9.98494	4	0			
1 -	L. Cos.	d.	L. Cotg.	d. c.	L.Tang.	L. Sin.	d.	Ť		P. P	

LOGARITHMS OF TRIGONOMETRIC FUNCTIONS.

_									
' 1	L. Sin.	d.	L.Tang.	d. c.	L. Cotg.	L. Cos.	d.		P. P.
0	9.41300		9.42805		0.57195	9.98494		60	
ĭ	9.41347	47	9.42856	51	0.57144	9.98491	3	59	
2	9.41394	47	9.42906	50	0.57094	9.98488	3	58	
3	9.41441	47	9.42957	51	0.57043	9.98484	4	57	51 50
4	9.41488	47	9.43007	50	0.56993	9.98481	3	56	6 5.1 5.0
5	9.41535	47	9.43057	50	0.56943	9.98477	4	55	7 6.0 5.8
		47	9.43057	51	0.56892	9.98474	3	54	8 6.8 6.7
6	9.41582 9.41628	46	9.43158	50	0.56842	9.98471	3	53	9 7.7 7.5
8	9.41675	47	9.43208	50	0.56792	9.98467	4	52	10 8.5 8.3 20 17.0 16.7
9		47	9.43258	50	0.56742	9.98464	3	51	
	9.41722	46		50			4		
10	9.41768	47	9.43308	50	0.56692	9.98460	3	50	
11	9.41815	46	9.43358	50	0.56642	9.98457	4	49	50 42.5 41.7
12	9.41861	47	9.43408	50	0.56592	9.98453	3	48	
13	9.41908	46	9.43458	50	0.56542	9.98450	3	47	
14	9.41954	47	9.43508	50	0.56492	9.98447	4	46	49 48
15	9.42001		9.43558		0.56442	9.98443		45	6 4.9 4.8
16	9.42047	46	9.43607	49	0.56393	9.98440	3 4	44	7 5.7 5.6
17	9.42093	46	9.43657	50	0.56343	9.98436		43	8 6.5 6.4
18	9.42140	47	9.43707	50.	0.56293	9.98433	3	42	9 7.4 7.2
19	9.42186	46	9.43756	49	0.56244	9.98429	4	41	10 8.2 8.0
20	9.42232	46	9.43806	50	0.56194	9.98426	3	40	20 16.3 16.0
21	9.42278	46	9.43855	49	0.56145	9.98422	4	39	30 24.5 24.0
22	9.42324	46	9.43905	50	0.56095	9.98419	3	38	40 32.7 32.0
23	9.42370	46	9.43954	49	0.56046	9.98415	4	37	50 40.8 40.0
24	9.42416	46	9.44004	50	0.55996	9.98412	3	36	
		45		49		9.98409	3	35	
25	9.42461	46	9.44053	49	0.55947		4	34	47 46
26	9.42507	46	9.44102	49	0.55898	9.98405	3	33	6 4.7 4.6
27	9.42553	46	9.44151	50	0.55849	9.98402	4	32	7 5.5 5.4
28		45	9.44201	49	0.55799	9.98398	3	31	8 6.3 6.1
29		46	9.44250	49	0.55750	9.98395	4		9 7.1 6.9
30		1	9.44299		0.55701	9.98391		30	10 7.8 7.7
31	9.42735	45	9.44348	49	0.55652	9.98388	3 4	29	20 15.7 15.3
32	9.42781	46	9.44397	49	0.55603	9.98384		28	30 23.5 23.0
33		45	9.44446	49	0.55554	9.98381	3.	27	40 31.3 30.7
\ 34	9.42872	46 45	9.44495	49 49	0.55505	9.98377	4	26	50 39.2 38.3
35	9.42917		9.44544		0.55456	9.98373		25	00 1 00.00 1 00.00
36		45	9.44592	48	0.55408	9.98370	3	24	
37		46	9.44641	49	0.55359	9.98366	4	23	
1 38	9.43053	45	9.44690	49	0.55310	9.98363	3	22	45 44
39		45	9.44738	48	0.55262	9.98359	4	21	6 4.5 4.4
40		45	9,44787	49	0.55213	9.98356	3	20	7 5.3 5.1
4		45	9.44836	49	0.55164	9.98352	4	19	8 6.0 5.9
14		45	9.44884	48	0.55116	9.98349	3	18	9 6.8 6.6
4		45	9.44933	49	0.55067	9.98345	4	17	10 7.5 7.3 20 15.0 14.7
4		45	9.44981	48	0.55019	9.98342	3	16	20 15.0 14.7
-		44		48			4		30 22.5 22.0
14		45	9.45029	49	0.54971	9.98338	4	15	40 30.0 29.3
4		45	9.45078	48	0.54922	9.98334	3	14	50 37.5 36.7
4		45	9.45126	48	0.54874	9.98331	4	13	
	8 9.43502	44	9.45174	48	0.54826	9.98327	3	12	
	9 9.43546	45	9.45222	49	0.54778	9.98324	4	11	4 3
5		_	9.45271	1 -	0.54729	9.98320		10	6 0.4 0.3
	9.43635	44	9.45319	48	0.54681	9.98317	3 4	9	7 0.5 0.4
(5	2 9.43680	45	9.45367	48	0.54633	9.98313	4	8	8 0.5 0.4
	3 9.43724	44	9.45415	48	0.54585	9.98309		7	9 0.6 0.5
5	4 9.43769	45	9.45463	48	0.54537	9.98306	3	6	10 0.7 0.5
	5 9,43813	44	9.45511	48	0.54489	9.98302	4	5	20 1.3 1.0
	6 9.43857	44	9.45559	48	0.54141	9.98299	3	4	30 2.0 1.5
- 13	9,43901	44	9.45606	47	0.54394	9.98295	4	3	40 2.7 2.0
	58 9.43946	45	9.45654	48	0.54346	9.98291	4	2	50 3.3 2.5
- 13	9.43990	44	9.45702	48	0.54298	9.98288	3	l ĩ l	
I	9.44034	44	9.45750	48	0.54250	9.98284	4	0	
- 15		-		d c			d.		
L	L. Cos.	d.	L. Cotg.	d. c.	L.Tang.	L. Sin.	u.		P. P.
					740				

					16°						
	L. Sin.	d.	L.Tang.	d. c.	L. Cotg.	L. Cos.	d.			P. 1	Р.
0	9.44034	44	9.45750 9.45797	47	0.54250 0.54203	9.98284 9.98281	3	60 59	l		
$\begin{bmatrix} 1 \\ 2 \end{bmatrix}$	9.44078 9.44122	44	9.45797	48	0.54203	9.98277	4	58	l		
3	9.44166	44	9.45892	47	0.54108	9.98273	4	57	ء ا	48 4.8	4
4	9.44210	44 43	9.45940	48 47	0.54060	9.98270	3 4	56	6 7	5.6	5
5	9.44253	44	9.45987		0.54013	9.98266	4	55	8	6.4	6.
6	9.44297	44	9.46035	48 47	0.53965	9.98262	3	54	9	7.2	7
7 8	9.44341 9.44385	44	9.46082 9.46130	48	0.53918 0.53870	9.98259 9.98255	4	53 52	10 20	8.0 16.0	
9	9.44428	43	9.46177	47	0.53823	9.98251	4	51	30	24.0	23
10	9.44472	44	9.46224	47	0.53776	9.98248	3	50	40	32.0	
ii	9.44516	44	9.46271	47	0.53729	9.98244	4	49	50	40.0	39
12	9.44559	43 43	9.46319	48 47	0.53681	9.98240	4 3	48	l		
13	9.44602	44	9.46366	47	0.53634 0.53587	9.98237 9.98233	4	47 46	l		
14	9.44646	43	9.46413	47		9.98229	4	45	ء ا	46	4
15 16	9.44689 9.44733	44	9.46460 9.46507	47	0.53540 0.53493	9.98229	3	44	6 7	4.6 5.4	
17	9.44776	43	9.46554	47	0.53446	9.98222	4	43 42	8	6.1	6.
18	9.44819	43	9.46601	47	0.53399	9.98218	4 3		9	6.9	6.
19	9.44862	43 43	9.46648	47 46	0.53352	9.98215	4	41	10	7.7	7. 15.
20	9.44905	43	9.46694	47	0.53306	9.98211	4	40	20 30	15.3 23.0	22.
21 22	9.44948 9.44992	44	9.46741 9.46788	47	0.53259 0.53212	9.98207 9.98204	3	39 38	40	30.7	30.
23	9.44992	43	9.46835	47	0.53165	9.98200	4	37	50	38.3	37.
24	9.45077	42	9.46881	46	0.53119	9.98196	4	36			
25	9.45120	43	9.46928	47	0.53072	9.98192	4	35	ŀ		
26	9.45163	43 43	9.46975	47	0.53025	9.98189	3 4	34		44	43
27	9.45206	43	9.47021	46 47	0.52979	9.98185 9.98181	4	33 32	6 7	4.4 5.1	5.
28 29	9.45249 9.45292	43	9.47068 9.47114	46	0.52886	9.98177	4	31	8	5.9	5.
30	9.45334	42	9.47160	46	0.52840	9.98174	3	30	9	6.6	6.
31	9.45377	43	9.47207	47	0.52793	9.98170	4	29	10	7.3	7. 14.
32	9.45419	42	9.47253	46	0.52747	9.98166	4	28	20 30	14.7 22.0	21.
33	9.45462	43 42	9.47299	46 47	0.52701 0.52654	9.98162	3	27 26	40	29.3	28.
34	9.45504	43	9.47346	46		9.98159	4	25	50	36.7	35.
35 36	9.45547 9.45589	42	9.47392 9.47438	46	0.52608 0.52562	9.98155 9.98151	4	220			
37	9.45632	43	9.47484	46	0.52516	9.98147	4	23	ľ		
38	9.45674	42	9.47530	46	0.52470	9.98144	3	22	6	42 4.2	41
39	9.45716	42 42	9.47576	46 46	0.52424	9.98140	4	21	7	4.2	4.
40	9.45758	43	9.47622	46	0.52378	9.98136	4	20	8	5.6	5.6
41 42	9.45801 9.45843	42	9.47668 9.47714	46	0.52332 0.52286	9.98132 9.98129	3	19 18	9	6.3	6.
43	9.45885	42	9.47760	46	0.52240	9.98125	4	17	10 20	7.0 14.0	13.
44	9.45927	42	9.47806	46	0.52194	9.98121	4	16	30	21.0	20.5
45	9.45969	42	9.47852	46	0.52148	9.98117	_	15	40	28.0	27.8
46	9.46011	42 42	9.47897	45 46	0.52103	9.98113	4 3	14	50	35.0	34.2
47	9.46053	42	9.47943 9.47989	46	0.52057 0.52011	9.98110 9.98106	4	13 12	1		
48 49	9.46095 9.46136	41	9.47989	46	0.51965	9.98100	4	11	l		
50	9.46178	42	9.48080	45	0.51920	9.98098	4	10	١,	4 5 0.4	0.3
51	9.46220	42	9.48126	46	0.51874	9.98094	4	9	1 3		0.3
52	9.46262	42	9.48171	45	0.51829	9.98090	4 3	8	8	0.5	0.4
53	9.46303	41 42	9.48217	46 45	0.51783	9.98087	4	7	9	0.6	0.5
54	9.46345	41	9.48262	45	0.51738	9.98083	4	6	10		0.5
55	9.46386	42	9.48307	46	0.51693	9.98079	4	5 4	20		1.0
56 57	9.46428 9.46469	41	8.48353 9.48398	45	0.51647 0.51602	9.98075 9.98071	4	3	40		2.0
58	9.46511	42	9.48443	45	0.51557	9.98067	4	2	50		2.5
59	9.46552	41	9.48489	46	0.51511	9.98063	4	ī	l		-
60	9.46594	42	9.48534	45	0.51466	9.98060	3	0	l		
-	L. Cos.	d.	L. Cotg.	d. c.	L.Tang.	L. Sin.	đ.	 		P. P	

					17°							
′ 1	L. Sin.	đ.	L.Tang.	d. c.	L. Cotg.	L. Cos.	đ.		I	P. I	2.	٦
0	9.46594	41	9.48534	45	0.51466	9.98060	4	60				_
1	9.46635	41	9.48579	45	0.51421	9.98056	4	59				1
3	9.46676 9.46717	41	9.48624 9.48669	45	0.51376 0.51331	9.98052 9.98048	4	58 57		45	44	
4	9.46758	41	9.48714	45	0.51286	9.98044	4	56	6	4.5		
5	9.46800	42	9.48759	45	0.51241	9.98040	4	55	8	5.3 6.0		
6	9.46841	41	9.48804	45	0.51196	9.98036	4	54	l ŝ	6.8		
7	9.46882	41	9.48849	45	0.51151	9.98032	4	53	10	7.5	7.	šІ
8	9.46923	41 41	9.48894	45 45	0.51106	9.98029	3	52	20	15.0		7
9	9.46964	41	9.48939	45	0.51061	9.98025	4	51	30 40	22.5 30.0		
10 11	9.47005 9.47045	40	9.48984 9.49029	45	0.51016 0.50971	9.98021 9.98017	4	50	50	37.5		
12	9.47086	41	9.49073	44	0.50927	9.98013	4	48	~	, 0	1 00.	۱.
13	9.47127	41	9.49118	45	0.50882	9.98009	4	47				- 1
14	9.47168	41 41	9.49163	45 44	0.50837	9.98005	4	46	l	-	13	- 1
15	9.47209	40	9.49207	45	0.50793	9.98001	4	45			4.3	- 1
16	9.47249	41	9.49252	44	0.50748	9.97997	4	44			5.0	- 1
17 18	9.47290 9.47330	40	9.49296 9.49341	45	0.50704	9.97993 9.97989	4	43 42			5.7 6.5	- 1
19	9.47371	41	9.49385	44	0.50615	9.97986	3	41	1		7.2	- 1
20	9.47411	40	9.49430	45	0.50570	9.97982	4	40	1 2	20 1	4.3	- 1
21	9.47452	41	9.49474	44	0.50526	9.97978	4	39		30 2	1.5	- 1
22	9.47492	40 41	9.49519	45 44	0.50481	9.97974	4	38		10 2 50 3	8.7 5.8	- 1
23	9.47533	40	9.49563	44	0.50437	9.97970	4	37	١ ،	N 34	0.0	- 1
24	9.47573	40	9.49607	45	0.50393	9.97966	4	36				- 1
25 26	9.47613 9.47654	41	9.49652 9.49696	44	0.50348 0.50304	9.97962 9.97958	4	35 34		42	1 41	١
27	9.47694	40	9.49090	44	0.50260	9.97954	4	33	6	4.2	4.	ı
28	9.47734	40	9.49784	44	0.50216	9.97950	4	32	7	4.9		
29	9.47774	40 40	9.49828	44 44	0.50172	9.97946	4	31	8 9	5.6		
30	9.47814	40	9.49872	44	0.50128	9.97942	4	30	10	6.3	6.	
31	9.47854	40	9.49916	44	0.50084	9.97938 9.97934	4	29 28	20	14.0	13.	
32 33	9.47894 9.47934	40	9.49960 9.50004	44	0.30040	9.97930	4	27	30	21.0		
34	9.47974	40	9.50048	44	0.49952	9.97926	4	26	40 50	28.0 35.0		
35	9.48014	40	9.50092	44	0.49908	9.97922	4	25	۳ ا	1 30.0	1 34.	ا '
36	9.48054	40	9.50136	44 44	0.49864	9.97918	4	24				
37	9.48094	40 39	9.50180	43	0.49820	9.97914	4	23		40	39	ı
38 39	9.48133 9.48173	40	9.50223 9.50267	44	0.49777 0.49733	9.97910 9.97906	4	22 21	6	4.0	3.9	9
		40	9.50207	44	0.49689	9.97902	4	20	7	4.7	4.	
40 41	9.48213 9.48252	39	9.50355	44	0.49645	9.97898	4	19	8	5.3 6.0		
42	9.48292	40	9.50398	43	0.49602	9.97894	4	18	10	6.7		
43	9.48332	40 39	9.50442	44 43	0.49558	9.97890	4	17	20	13.3	13.	0
44	9.48371	40	9.50485	44	0.49515	9.97886	4	16	30	20.0		
45	9.48411	39	9.50529	43	0.49471 0.49428	9.97882 9.97878	4	15 14	40 50	26.7 33.3		
46 47	9.48450 9.48490	40	9.50572 9.50616	44	0.49428	9.97874	4	13	۳ ا	00.0	1 02.	۰ ا
48	9.48529	39	9.50659	43	0.49341	9.97870	4	12	l			
49	9.48568	39	9.50703	44 43	0.49297	9.97866	4 5	11	1	5	4 1	3
50	9.48607	39	9.50746		0.49254	9.97861	4	10		0.5	0.4 (0.3
51	9.48647	40 39	9.50789	43 44	0.49211	9.97857	4	9				0.4
52	9.48686 9.48725	39	9.50833 9.50876	43	0.49167 0.49124	9.97853 9.97849	4	8 7				0.4 0.5
53 54	9.48725	39	9.50919	43	0.49081	9.97845	4	6).5).5
55	9.48803	39	9.50962	43	0.49038	9,97841	4	5	20	1.7	1.3 1	1.0
56	9.48842	39	9.51005	43	0.48995	9.97837	4	4			2.0 1	1.5
57	9.48881	39 39	9.51048	43 44	0.48952	9.97833	4	3		3.3 4.2	$\begin{array}{c c} 2.7 & 2 \\ 3.3 & 2 \end{array}$	2.0 2.5
58	9.48920	39	9.51092	43	0.48908	9.97829	4	2 1	00	1.4	0.0 2	ان.:
59	9.48959	39	9.51135	43	0.48865	9.97825	4		l			1
60	9.48998		9.51178		0.48822	9.97821		0				_
L	L. Cos.	d.	L. Cotg.	d. c.	L.Tang.	L. Sin.	d.	<u>'</u>	l	P. I		_

					18°						
1	L. Sin.	d.	L.Tang.	d. c.	L. Cotg.	L. Cos.	d.	1		P.	P.
0	9.48998	39	9.51178	43	0.48822	9.97821	4	60			
1 2	9.49037 9.49076	39	9.51221 9.51264	43	0.48779	9.97817 9.97812	5	59 58	l		
3	9.49115	39 38	9.51306	42 43	0.48694	9.97808	4	57	6	43	
4	9.49153	39	9.51349	43	0.48651	9.97804	4	56	7	5.	0 4.9
5 6	9.49192 9.49231	39	9.51392 9.51435	43	0.48608 0.48565	9.97800 9.97796	4	55 54	8		
7	9.49269	38	9.51478	43	0.48522	9.97792	4	53	9 10	6.	
8	9.49308	39 39	9.51520	42 43	0.48480	9.97788	4	52	20	14.	3 14.0
9	9.49347	38	9.51563	43	0.48437	9.97784	5	51	30 40	21.3 28.7	
10	9.49385 9.49424	39	9.51606 9.51648	42	0.48394 0.48352	9.97779 9.97775	4	50 49	50	35.8	35.0
12	9.49462	38 38	9.51691	43	0.48309	9.97771	4	48			•
13	9.49500 9.49539	39	9.51734	43 42	0.48266	9.97767	4	47			
14	9.49577	38	9.51776 9.51819	43	0.48224	9.97763	4	46			4! 4.1
16	9.49615	38	9.51861	42	0.48139	9.97754	5	40			4.8
17	9.49654	39 38	9.51903	42 43	0.48097	9.97750	4	43	ŀ	8	5.5
18 19	9.49692 9.49730	38	9.51946 9.51988	42	0.48054 0.48012	9.97746 9.97742	4	42 41	١.		6.2 6.8
20	9.49768	38	9.52031	43	0.43012	9.97738	4	40			3.7
21	9.49806	38	9.52031	42	0.47927	9.97734	4	39		30 20).5
22	9.49844	38 38	9.52115	42 42	0.47885	9.97729	5 4	38			7.3 1. 2
23	9.49882 9.49920	38	9.52157 9.52200	43	0.47843 0.47800	9.97725 9.97721	4	37 36	١ '	JU J	
25	9.49958	38	9.52242	42	0.47758	9.97717	4	35	i		
26	9.49996	38	9.52284	42	0.47716	9.97713	4	34		39	38
27	9.50034	38 38	9.52326	42 42	0.47674	9.97708	5 4	33	6	3.9	3.8 4.4
28 29	9.50072 9.50110	38	9.52368 9.52410	42	0.47632 0.47590	9.97704 9.97700	4	32 31	8	4.6 5.2	5.1
30	9.50148	38	9.52452	42	0.47548	9.97696	4	30	9	5.9	5.7
31	9.50185	37 38	9.52494	42	0.47506	9.97691	5	29	10 20	6.5 13.0	6.3 12.7
32	9.50223 9.50261	38	9.52536	42 42	0.47464 0.47422	9.97687	4	28 27	30	19.5	19.0
33	9.50201	37	9.52578 9.52620	42	0.47422	9.97683 9.97679	4	26	40	26.0	25.3
35	9.50336	38	9.52661	41	0.47389	9.97674	5	25	50	32.5	31.7
36	9.50374	38 37	9.52703	42 42	0.47297	9.97670	4	24			
37 38	9.50411 9.50449	38	9.52745	42	0.47255	9.97666	4	23 22		37	36
39	9.50486	37	9.52787 9.52829	42	0.47213 0.47171	9.97662 9.97657	5	21	6	3.7	3.6
40	9.50523	37	9.52870	41	0.47130	9.97653	4	20	7 8	4.3	4.2 4.8
41	9.50561	38 37	9.52912	42 41	0.47088	9.97649	4	19	9	5.6	5.4
42 43	9.50598 9.50635	37	9.52953 9.52995	42	0.47047 0.47005	9.97645 9.97640	5	18 17	10	6.2	6.0
44	9.50673	38 37	9.53037	42	0.46963	9.97636	4	16	20 30	12.3 18.5	12.0 18.0
45	9.50710		9.53078	41	0.46922	9.97632	4	15	40	24.7	24.0
46	9.50747	37 37	9.53120	42 41	0.46880	9.97628	4 5	14	50	30.8	30.0
47 48	9.50784 9.50821	37	9.53161 9.53202	41	0.46839 0.46798	9.97623 9.97619	4	13 12	l		
49	9.50858	37	9.53244	42	0.46756	9.97615	4	ii		5	ایر
50	9.50896	38 37	9.53285	41	0.46715	9.97610	5	:0	6		0.4
51	9.50933	37	9.53327	42 41	0.46673	9.97606	4	9	7	0.6	0.5
52 53	9.50970 9.51007	37	9.53368 9.53409	41	0.46632 0.46591	9.97602 9.97597	5	8 7	8		0.5
54	9.51043	36 37	9.53450	41	0.46550	9.97593	4	6	10	0.8	0.7
55	9.51080	37	9.53492	42 41	0.46508	9.97589	4 5	5	20	1.7	1.3
56	9.51117 9.51154	37	9.53533	41	0.46467	9.97584	4	4 3	30 40		2.0 2.7
58	9.51191	37	9.53574	41.	0.46426	9.97580 9.97576	4	2	50		3.3
59	9.51227	36 37	9.53656	41	0.46344	9.97571	5 4	1			ļ
60	9.51264		9.53697		0.46303	9.97567		0			
	L. Cos.	d.	L. Cotg.	d.c.	L.Tang.	L. Sin.	d.	' -	l '	P.P.	

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<u></u>	L. Sin.	đ.	L.Tang.	d. c.	L. Cotg.	L. Cos.	d.		P. P.
0	9.51264	0.5	9.53697	44	0.46303	9.97567		60	
1	9.51301	37 37	9.53738	41 41	0.46262	9.97563	4	59	
2	9.51338	36	9.53779	41	0.46221	9.97558	5 4	58	41 1 40
3 4	9.51374 9.51411	37	9.53820 9.53861	41	0.46180 0.46139	9.97554 9.97550	4	57	6 4.1 4.0
5		36		41			5	56	7 4.8 4.7
6	9.51447 9.51484	37	9.53902 9.53943	41	0.46098	9.97545	4	55	8 5.5 5.3
7	9.51520	36	9.53984	41	0.46057 0.46016	9.97541 9.97536	5	54 53	9 6.2 6.0
8	9.51557	37	9.54025	41	0.45975	9.97532	4	52	10 6.8 6.7 20 13.7 13.3
9	9.51593	36	9.54065	40	0.45935	9.97528	4	51	30 20.5 20.0
10	9.51629	36	9.54106	41	0.45894	9.97523	5	50	40 27.3 26.7
11	9.51666	37	9.54147	41	0.45853	9.97519	4	49	50 34.2 33.3
12	9.51702	36	9.54187	40 .	0.45813	9.97515	4	48	
13	9.51738	36 36	9.54228	41 41	0.45772	9 97510	5	47	, ,
14	9.51774	37	9.54269	40	0.45731	9.97506	4 5	46	39
15	9.51811	36	9.54309	41	0.45691	9.97501		45	6 3.9
16	9.51847	36	9.54350	40	0.45650	9.97497	4	44	7 4.6
17 18	9.51883	36	9.54390	41	0.45610	9.97492	5 4	43	8 5.2
19	9.51919 9.51955	36	9.54431 9.54471	40	0.45569	9.97488	4	42	9 5.9
		36		41	0.45529	9.97484	5	41	10 6.5 20 13.0
20	9.51991	36	9.54512	40	0.45488	9.97479	4	40	30 19.5
21 22	9.52027 9.52063	36	9.54552 9.54593	41	0.45448 0.45407	9.97475	5	39	40 26.0
23	9.52099	36	9.54633	40	0.45407	9.97470 9.97466	4	38 37	50 32.5
24	9.52135	36	9.54673	40	0.45327	9.97461	5	36	
25	9.52171	36	9.54714	41	0.45286	9.97457	4	35	
26	9.52207	36	9.54754	40	0.45246	9.97453	4	34	37 36
27	9.52242	35	9.54794	40	0.45206	9.97448	5	33	6 3.7 3.6
28	9.52278	36	9.54835	41	0.45165	9.97444	4	32	7 4.3 4.2
29	9.52314	36	9.54875	40	0.45125	9.97439	5	31	8 4.9 4.8
30	9.52350	36	9.54915	40	0.45085	9.97435	4	30	9 5.6 5.4
31	9.52385	35	9.54955	40	0.45045	9.97430	5	29	10 6.2 6.0
32	9.52421	36	9.54995	40	0.45005	9.97426	4	28	20 12.3 12.0 30 18.5 18.0
33	9.52456	35	9.55035	40	0.44965	9.97421	5	27	30 18.5 18.0 40 24.7 24.0
34	9.52492	36 35	9.55075	40 40	0.44925	9.97417	4 5	26	50 30.8 30.0
35	9.52527		9.55115		0.44885	9.97412		25	00 00.0 00.0
36	9.52563	36 35	9.55155	40	0.44845	9.97408	4 5	24	
37	9.52598	36	9.55195	40 40	0.44805	9.97403	4	23	35 34
38	9.52634	35	9 55235	40	0.44765	9.97399	5	22	6 3.5 3.4
	9.52669	36	9.55275	40	0.44725	9.97394	4	21	7 4.1 4.0
40	9.52705	35	9.55315	40	0.44685	9.97390	5	20	8 4.7 4.5
41	9.52740	35	9,55355	40	0.44645	9.97385	4	19	9 5.3 5.1
43		36	9.55395 9.55434	39	0.44605 0.44566	9.97381 9.97376	5	18 17	10 5.8 5.7
44		35 35	9.55474	40	0.44526	9.97372	4	16	20 11.7 11.3
45			9.55514	40	0.44486	9.97367	5	15	$\left egin{array}{c c c} 30 & 17.5 & 17.0 \\ 40 & 23.3 & 22.7 \end{array} \right $
146		35	9.55554	40	0.44486	9.97363	4	15	50 29.2 28.3
47		35	9.55593	39	0.44407	9.97358	5 5	13	00 20 2000
48	9.52986	35	9.55633	40	0.44367	9.97353	5	12	
49	9.53021	35 35	9.55673	40	0.44327	9.97349	4	11	5 4
50			9.55712	39	0.44288	9.97344	5	10	6 0.5 0.4
5		36 34	9.55752	40	0.44248	9.97340	4	9	7 0.6 0.5
5		35	9.55791	39 40	0.44209	9.97335	5 4	8	8 0.7 0.5
5		35	9.55831	39	0.44169	9.97331	5	7	9 0.8 0.6
		35	9.55870	40	0.44130	9.97326	4	6	10 0.8 0.7
5	9.53231	35	9.55910	39	0.44090	9.97322		5	$egin{array}{c c c} 20 & 1.7 & 1.3 \\ 30 & 2.5 & 2.0 \\ \hline \end{array}$
15	6 9.53266 7 9.53301	35	9.55949	40	0.44051	9.97317	5	4	30 2.5 2.0 40 3.3 2.7
5	8 9.53336	35	9.55989 9.56028	39	0.44011 0.43972	9.97312 9.97308	4	3 2	50 4.2 3.3
5		34	9.56067	39	0.43933	9.97303	5	í	-5 , 2.2 , 5.0
8		35	9.56107	40	0.43893	9.97299	4	-	
-		d.		4	face of the second			,	P. P.
L.	L. Cos.	i a.	L. Cotg.	а. с.	L.Tang.	L. Sin.	d.	<u> </u>	r, r,

					20°						
′	L. Sin.	d.	L.Tang.	d. c.	L. Cotg.	L. Cos.	d.			P. 1	۲.
0	9.53405 9.53440	35	9.56107 9.56146	39	0.43893 0.43854	9.97299 9.97294	5	60 59			7
$\frac{1}{2}$	9.53475	35	9.56185	39	0.43815	9.97289	5	58	l		
2 3	9.53509	34	9.56224	39	0.43776	9.97285	4	57	6	40	36 3.5
4	9.53544	35 34	9.56264	40 39	0.43736	9.97280	5 4	56	7	4.7	4.4
5	9.53578	35	9.56303	39	0.43697	9.97276	5	55	8	5.3	5.1
6 7	9.53613 9.53647	34	9.56342 9.56381	39	0.43658 0.43619	9.97271 9.97266	5	54 53	9 10	6.7	
8	9.53682	35	9.56420	39	0.43580	9.97262	4	52	20	13.3	
9	9.53716	34 35	9.56459	39 39	0.43541	9.97257	5 5	51	30	20.0	19.5
10	9.53751	34	9.56498	39	0.43502	9.97252	4	50	40 50	26.7	
11 12	9.53785 9.53819	34	9.56537 9.56576	39	0.43463 0.43424	9.97248 9.97243	5	49 48	90	33.3	34.
13	9.53854	35	9.56615	39	0.43385	9.97238	5	47			
14	9.53888	34	9.56654	39	0.43346	9.97234	4	46	İ	38	37
15	9.53922	34 35	9.56693	39	0.43307	9.97229	5	45	6	3.8	3.7
16	9.53957	34	9.56732	39 39	0.43268	9.97224	5	44	7	4.4	4.3
17 18	9.53991 9.54025	34	9.56771 9.56810	- 39	0.43229 0.43190	9.97220 9.97215	5	43 42	8	5.1 5.7	4.9 5.6
19	9.54059	34	9.56849	39	0.43151	9.97210	5	41	10	6.3	6.2
20	9.54093	34	9.56887	38	0.43113	9.97206	4	40	20	12.7	12.3
21	9.54127	34	9.56926	39	0.43074	9.97201	5	39	30 40	19.0	18.5 24.7
22	9.54161	34 34	9.56965	39 39	0.43035	9.97196	5 4	38	50	25.3 31.7	30.8
$\frac{23}{24}$	9.54195 9.54229	34	9.57004 9.57042	38	0.42996 0.42958	9.97192 9.97187	5	37 36	00	01.7	1 00.0
25	9.54263	34	9.57081	39	0.42919	9.97182	5	35			
26	9.54297	34	9.57120	39	0.42880	9.97178	4	34			35
27	9.54331	34	9.57158	38	0.42842	9.97173	5	33			3.5
28	9.54365	34 34	9.57197	39 38	0.42803	9.97168	5 5	32			4.1 4.7
29	9.54399	34	9.57235	39	0.42765	9.97163	4	31	l		5.3
30 31	9.54433 9.54466	33	9.57274 9.57312	38	0.42726 0.42688	9.97159 9.97154	5	30 29		LÕ	5.8
32	9.54500	34	9.57351	39	0.42649	9.97149	5	28	1 2	20 1	1.7
33	9.54534	34	9.57389	38	0.42611	9.97145	4	27			7.5 3.3
34	9.54567	33 34	9.57428	39 38	0.42572	9.97140	5	26			9.2
35	9.54601	34	9.57466	38	0.42534	9.97135	5	25		•	
36 37	9.54635 9.54668	33	9.57504 9.57543	39	0.42496 0.42457	9.97130 9.97126	4	24 23			
38	9.54702	34	9.57581	38	0.42419	9.97121	5	22		34	33
39	9.54735	33	9.57619	38 39	0.42381	9.97116	5 5	21	6 7	3.4 4.0	3.3
40	9.54769	34	9.57658		0.42342	9.97111		20	8	4.5	4.4
41	9.54802	33 34	9.57696	38 38	0.42304	9.97107	4 5	19	9	5.1	5.0
42 43	9.54836 9.54869	33	9.57734 9.57772	38	0.42266	9.97102 9.97097	5	18 17	10	5.7	5.5
44	9.54903	34	9.57810	38	0.42190	9.97092	5	16	20 30	11.3 17.0	11.0 16.5
45	9.54936	33	9.57849	39	0.42151	9.97087	5	15	40	22.7	22.0
46	9.54969	33	9.57887	38 38	0.42113	9.97083	4	14	50	28.3	27.5
47	9.55003	34 33	9.57925	38	0.42075 0.42037	9.97078 9.97073	5 5	13 12	1		
48 49	9.55036 9.55069	33	9.57963	38	0.42037	9.97078	5	11		_	
50	9.55102	33	9.58039	38	0.41961	9.97063	5	10	6	5 0.5	0.4
51	9.55136	34	9.58077	38	0.41923	9.97059	4	9	7	0.6	0.5
52	9.55169	33	9.58115	38 38	0.41885	9.97054	5 5	8	8	0.7	0.5
53 54	9.55202	33 33	9.58153	38	0.41847 0.41809	9.97049 9.97044	5	7 6	19	0.8	0.6
	9.55235	33	9.58191	38	0.41771		5	$\frac{6}{5}$	10 20	0.8 1.7	0.7 1.3
55 56	9.55268 9.55301	33	9.58229 9.58267	38	0.41771	9.97039 9.97035	. 4	4	30	2.5	2.0
57	9.55334	33	9.58304	37	0.41696	9.97030	5	3	40	3.3	2.7
58	9.55367	33 33	9.58342	38 38	0.41658	9.97025	5 5	2	50	4.2	3.3
59	9.55400	33	9.58380	38	0.41620	9.97020	5	1			- 1
60	9.55433		9.58418		0.41582	9.97015		0			
	L. Cos.	d.	L. Cotg.	d. c.	L.Tang.	L. Sin.	d.	_′_		P. P	

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	I	. Sin.	d.	L.Tang.	d. c.	L. Cotg.	L. Cos.	d.		_	P. P.	
0	9	.55433		9.58418		0.41582	9.97015		60			
1		.55466	33	9.58455	37	0.41545	9.97010	5	59	}		
2		.55499	33 33	9.58493	38 38	0.41507	9.97005	5 4	58		38	37
3		.55532	32	9.58531	38	0.41469	9.97001	5	57	6	3.8	3.7
4	_	.55564	33	9.58569	37	0.41431	9.96996	5	56	7	4.4	4.3
5		.55597	33	9.58606	38	0.41394	9.96991	5	55	8	5.1	4.9
6 7		.55630 .55663	33	9.58644 9.58681	37	0.41356 0.41319	9.96986 9.96981	5	54 53	9	5.7	5.6
ś		.55695	32	9.58719	38	0.41313	9.96976	5	52	10 20	6.3 12.7	$\frac{6.2}{12.3}$
ğ		.55728	33	9.58757	38	0.41243	9.96971	5	51	30	19.0	18.5
10		.55761	33	9.58794	37	0.41206	9.96966	5	50	40	25.3	24.7
iĭ		0.55793	32	9.58832	38	0.41168	9.96962	4	49	50	31.7	30.8
12		0.55826	33 32	9.58869	37	0.41131	9.96957	5	48		•	•
13		9.55858	32	9.58907	38	0.41093	9.96952	5	47			
14	5	0.55891	33 32	9.58944	37 37	0.41056	9.96947	5 5	46		36	33
15		9.55923		9.58981		0.41019	9.96942		45	6	3.6	3.3
16		9.55956	33 32	9.59019	38	0.40981	9.96937	5	44	7	4.2	3.9
17		9.55988	92	9.59056	37 38	0.40944	9.96932	5	43	8	4.8	4.4
18		9.56021	33 32	9.59094	37	0.40906	9.96927	5 5	42	9	5.4	5.0
19	-1-	9.56053	32	9.59131	37	0.40869	9.96922	5	41	10	6.0	5.5
20		9.56085	33	9.59168	37	0.40832	9.96917	5	40	20 30	12.0 18.0	11.0 16.5
21		9.56118 9.56150	32	9.59205	38	0.40795	9.96912	5	39	40	24.0	22.0
2		9.56182	32	9.59243 9.59280	37	0.40757 0.40720	9.96907 9.96903	4	38 37	50	30.0	
1 2		9.56215	33	9.59317	37 37	0.40683	9.96898	5	36			
2	_	9.56247	32	9.59354	37		9.96893	5 5				
1 2		9.56279	32	9.59391	37	0.40646 0.40609	9.96888	5	35 34		3	2
1 2		9.56311	32	9.59429	38	0.40571	9.96883	5	33		6 3	.2
1 2		9.56343	32	9.59466	37	0.40534	9.96878	5	32		7 3	.7
2	9	9.56375	32	9.59503	37	0.40497	9.96873	5	31			.3
3	٦ľ	9.56408	33	9.59540	37	0.40460	9.96868	5	30			.8
3		9.56440	32	9.59577	37	0.40423	9.96863	5 5 5	29			.3
3		9.56472	32 32	9.59614	37 37	0.40386	9.96858	Đ	28		20 10 30 16	
3		9.56504	32 32	9.59651	37	0.40349	9.96853	5	27		40 21	
3		9.56536	32	9.59688	37	0.40312	9.96848	5	26		50 26	
	5	9.56568	31	9.59725	37	0.40275	9.96843	5	25			
13	6	9.56599	32	9.59762	37	0.40238	9.96838	5	24			
	7 8	9.56631 9.56663	32	9.59799	36	0.40201	9.96833	5	23		31	6
	9	9.56695	32	9.59835 9.59872	37	0.40165 0.40128	9.96828 9.96823	5	22 21	6	3.1	0.6
	0	9.56727	32		37			5		7	3.6	0.7
	ŭ	9.56759	32	9.59909 9.59946	37	0.40091 0.40054	9.96818 9.96813	5	20	8	4.1	0.8
	12	9.56790	31	9.59983	37	0.40017	9.96808	5	19 18	9	4.7	0.9
	43	9.56822	32	9.60019	36	0.39981	9.96803	5 5	17	10	5.2	1.0
	44	9.56854	32	9.60056	37	0.39944	9.96798	5	16	20 30	10.3 15.5	3.0
- 1-	45	9.56886	32	9.60093	37	0.39907	9.96793	5	15	40	20.7	4.0
	46	9.56917	31	9.60130	37	0.39870	9.96788	5	14	50	25.8	5.0
- 1	47	9.56949	32	9.60166	36	0.39834	9.96783	5 5	13			
1	48	9.56980	31 32	9.60203	37 37	0.39797	9.96778	6	12			
١.	49	9.57012	32	9.60240	36	0.39760	9.96772	5	11		5	4
- 1	50	9.57044	31	9.60276	37	0.39724	9.96767	5	10	6	0.5	0.4
- 1	51	9.57075	32	9.60313	36	0.39687	9.96762	5	9	7	0.6	0.5
- 1	52 52	9.57107	31	9.60349	37	0.39651	9.96757	5	8	8		0.5
	53 54	9.57138 9.57169	31	9.60386 9.60422	36	0.39614 0.39578	9.96752 9.96747	5 5 5	7	9		0.6
1			32		37			5		10		0.7
- 1	55 56	9.57201 9.57232	31	9.60459	36	0.39541	9.96742	5	5	20 30		$\frac{1.3}{2.0}$
	57	9.57264	32	9.60495 9.60532	37	0.39505 0.39468	9.96737 9.96732	5	4 3	40		2.7
	58	9.57295	31	9.60568	36	0.39432	9.96727	5	2	50		3.3
	59	9.57326	31	9.60605	37	0.39395	9.96722	5	ĩ			
	60	9.57358	32	9.60641	36	0.39359	9.96717	5	0			
		L. Cos.	d.		4.0			d.			D D	
		L. CO8.	u.	L. Cotg.	d. c.	L.Tang.	L. Sin.	լ ս.	l '		P. P.	

					22°				
1	L. Sin.	d.	L.Tang.	d. c.	L. Cotg.	L. Cos.	đ.		P. P.
0	9.57358	31	9.60641	36	0.39359	9.96717		60	
1 2	9.57389 9.57420	31	9.60677 9.60714	37	0.39323 0.39286	9.96711 9.96706	6 5	59 58	
3	9.57451	31	9.60750	36	0.39250	9.96701	5 5	57	37 38
4	9.57482	31	9.60786	36 37	0.39214	9.96696	5	56	$egin{array}{ c c c c c c c c c c c c c c c c c c c$
5	9.57514	32	9.60823	36	0.39177	9.96691	5	55	8 4.9 4.8
6	9.57545	31 31	9.60859	36	0.39141	9.96686	5 5	54	9 5.6 5.4
7 8	9.57576 9.57607	31	9.60895 9.60931	36	0.39105	9.96681 9.96676	5	53 52	10 6.2 6.0 20 12.3 12.0
9	9.57638	31	9.60967	36	0.39033	9.96670	6	51	20 12.3 12.0 30 18.5 18.0
10	9.57669	31	9.61004	37	0.38996	9.96665	5	50	40 24.7 24.0
11	9.57700	31 31	9.61040	36 36	0.38960	9.96660	5 5	49	50 30.8 30.0
12 13	9.57731 9.57762	31	9.61076 9.61112	36	0.38924 0.38888	9.96655 9.96650	5	48 47	
14	9.57793	31	9.61148	36	0.38852	9.96645	5	46	35
15	9.57824	31	9.61184	36	0.38816	9.96640	5	45	6 3.5
16	9.57855	31	9.61220	36 36	0.38780	9.96634	6	44	7 4.1
17	9.57885	30 31	9.61256	36	0.38744	9.96629	5 5	43	8 4.7
18 19	9.57916 9.57947	31	9.61292 9.61328	36	0.38708 0.38672	9.96624 9.96619	5	42 41	9 5.3 10 5.8
20	9.57978	31	9.61364	36	0.38636	9.96614	5	40	20 11.7
21	9.58008	30	9.61400	36	0.38600	9.96608	6	39	30 17.5
22	9.58039	31 31	9.61436	36 36	0.38564	9.96603	5 5	38	40 23.3 50 29.2
23	9.58070	31	9.61472	36	0.38528	9.96598	5	37	50 29.2
24	9.58101	30	9.61508	36	0.38492	9.96593	5	36	
25 26	9.58162	31	9.61544	35	0.38421	9.96582	6	34	32 31
27	9.58192	30	9.61615	36	0.38385	9.96577	5	33	6 3.2 3.1
28	9.58223	31 30	9.61651	36 36	0.38349	9.96572	5	32	7 3.7 3.6
29	9.58253	31	9.61687	35	0.38313	9.96567	5	31	8 4.3 4.1 9 4.8 4.7
30 31	9.58284 9.58314	30	9.61722	36	0.38278 0.38242	9.96562 9.96556	6	30	10 5.3 5.2
32	9.58345	31	9.61758 9.61794	36	0.38206	9.96551	5	29 28	20 10.7 10.3
33	9.58375	30	9.61830	36	0.38170	9.96546	5	27	30 16.0 15.5 40 21.3 20.7
34	9.58406	31 30	9.61865	35 36	0.38135	9.96541	5 6	26	50 26.7 25.8
35	9.58436	31	9.61901	35	0.38099	9.96535	5	25	, ,
36 37	9.58467 9.58497	30	9.61936 9.61972	36	0.38064 0.38028	9.96530 9.96525	5	24 23	
38	9.58527	30	9.62008	36	0.37992	9.96520	5	22	30 29
39	9.58557	30 31	9.62043	35 36	0.37957	9.96514	6 5	21	6 3.0 2.9 7 3.5 3.4
40	9.58588	30	9.62079	35	0.37921	9.96509	5	20	8 4.0 3.9
41	9.58618	30 30	9.62114	36	0.37886	9.96504	6	19	9 4.5 4.4
42 43	9.58648 9.58678	30	9.62150 9.62185	35	0.37850 0.37815	9.96498 9.96493	5	18 17	10 5.0 4.8
44	9.58709	31	9.62221	36	0.37779	9.96488	5	16	20 10.0 9.7 30 15.0 14.5
45	9.58739	30	9.62256	35	0.37744	9.96483	5	15	40 20.0 19.3
46	9.58769	30 30	9.62292	36 35	0.37708	9.96477	6 5	14	50 25.0 24.2
47 48	9.58799 9.58829	30	9.62327 9.62362	35	0.37673 0.37638	9.96472 9.96467	5	$\frac{13}{12}$	1
49	9.58859	30	9.62398	36	0.37602	9.96461	6	ii	1
50	9.58889	30	9.62433	35	0.37567	9.96456	5	賣	6 0.6 0.5
51	9.58919	30 30	9.62468	35 36	0.37532	9.96451	5	9	7 0.7 0.6
52	9.58949	30 30	9.62504	35	0.37496	9.96445	6 5	8 7	8 0.8 0.7
53 54	9.58979 9.59009	30	9.62539 9.62574	85	0.37461 0.37426	9.96440 9.96435	5 5	6	9 0.9 0.8 10 1.0 0.8
55	9.59039	30	9.62609	35	0.37391	9.96429	6	5	20 2.0 1.7
56	9.59069	30	9.62645	36	0.37355	9.96424	5 5	4	30 3.0 2.5
57	9.59098	29 30	9.62680	35 35	0.37320	9.96419	5 6	3	40 4.0 3.3
58 59	9.59128 9.59158	30	9.62715 9.62750	35	0.37285	9.96413	5	$\begin{vmatrix} 2\\1 \end{vmatrix}$	50 5.0 4.2
60	9.59188	30	9.62785	35	$\begin{array}{ c c c c c c c c c c c c c c c c c c c$	9.96408	5	-	
	L. Cos.	<u>d</u> .		A .			d.	ا ا	P. P.
!	L. COS.	u.	L. Cotg.	d. c.	L.Tang.	L. Sin.	a.	1 1	r.r.

					23°				
'	L. Sin.	đ.	L.Tang.	d. c.	L. Cotg.	L. Cos.	d.		P. P.
0	9.59188	30	9.62785	35	0.37215	9.96403	6	60	
1 2	9.59218 9.59247	29	9.62820 9.62855	35	0.37180	9.96397 9.96392	5	59 58	
3	9.59247	30	9.62890	35 35	0.37110	9.96387	5	57	36 35
4	9.59307	30	9.62926	36	0.37074	9.96381	6	56	$egin{array}{c c c} 6 & 3.6 & 3.5 \ 7 & 4.2 & 4.1 \ \end{array}$
5	9.59336	29	9.62961	35	0.37039	9.96376	5	55	8 4.8 4.7
6	9.59366	30 30	9.62996	35 35	0.37004	9.96370	6 5	54	9 5.4 5.3
7	9.59396	29	9.68031	35	0.36969	9.96365	5	53	10 6.0 5.8
8	9.59425 9.59455	30	9.63066 9.63101	35	0.36934 0.36899	9.96360 9.96354	6	52 51	20 12.0 11.7 30 18.0 17.5
10	9.59484	29	9.63135	34	0.36865	9.96349	5	50	40 24.0 23.3
11	9.59514	30	9.63170	35	0.36830	9.96343	6	49	50 30.0 29.2
12	9.59543	29	9.63205	35 ·	0.36795	9.96338	5	48	
13	9.59573	30 29	9.63240	35 35	0.36760	9.96333	5 6	47	
14	9.59602	30	9.63275	35	0.36725	9.96327	5	46	34
15	9.59632	29	9.63310 9.63345	35	0.36690	9.96322	6	45 44	6 3.4 7 4.0
16 17	9.59661 9.59690	29	9.63379	34	0.36655 0.36621	9.96316 9.96311	5	43	7 4.0 8 4.5
18	9.59720	30	9.63414	35	0.36586	9.96305	6	42	9 5.1
19	9.59749	29 29	9.63449	35 35	0.36551	9.96300	5 6	41	10 5.7
20	9.59778	30	9.63484	35	0.36516	9.96294		40	20 11.3 30 17.0
21	9.59808	29	9.63519	34	0.36481	9.96289	5 5	39	30 17.0 40 22.7
22 23	9.59837 9.59866	29	9.63553 9.63588	35	0.36447 0.36412	9.96284 9.96278	6	38 37	50 28.3
24	9.59895	29	9.63623	35	0.36377	9.96273	5	36	,
25	9.59924	29	9.63657	84	0.36343	9.96267	6	35	
26	9.59954	30	9.63692	35	0.36308	9.96262	5	34	30 29
27	9.59983	29 29	9.63726	34 35	0.36274	9.96256	6 5	33	6 3.0 2.9
28 29	9.60012 9.60041	29	9.63761 9.63796	35	0.36239	9.96251 9.96245	6	32 31	7 3.5 3.4 8 4.0 3.9
		29		34			5		9 4.5 4.4
30 31	9.60070 9.60099	29	9.63830 9.63865	35	0.36170	9.96240 9.96234	6	30 29	10 5.0 4.8
32	9.60128	29	9.63899	34	0.36101	9.96229	5	28	20 10.0 9.7 30 15.0 14.5
33	9.60157	29 29	9.63934	35 . 34	0.36066	9.96223	6 5	27	30 15.0 14.5 40 20.0 19.3
34	9.60186	29	9.63968	35	0.36032	9.96218	6	26	50 25.0 24.2
35	9.60215	29	9.64003	34	0.35997	9.96212	5	25	
36 37	9.60244 9.60273	29	9.64037 9.64072	35	0.35963 0.35928	9.96207 9.96201	6	24 23	
38	9.60302	29	9.64106	34	0.35894	9.96196	5	22	28
39	9.60331	29	9.64140	34	0.35860	9.96190	6	21	6 2.8
40	9.60359	28	9.64175	35	0.35825	9.96185	5	20	7 3.3 8 3.7
41	9.60388	29	9.64209	34 34	0.35791	9.96179	6 5	19	9 4.2
42 43	9.60417 9.60446	29 29	9.64243 9.64278	35	0.35757 0.35722	9.96174 9.96168	6	18 17	10 4.7
43	9.60474	28	9.64312	34	0.35688	9.96162	6	16	20 9.3 30 14.0
45	9.60503	29	9.64346	34	0.35654	9.96157	5	15	30 14.0 40 18.7
46	9.60532	29	9.64381	35	0.35619	9.96151	6	14	50 23.3
47	9.60561	29 28	9.64415	34 34	0.35585	9.96146	5 6	13	'
48	9.60589	29	9.64449	34	0.35551	9.96140	5	12 11	
49	9.60618	28	9.64483	34	0.35517	9.96135	6		6 5
50 51	9.60646 9.60675	29	9.64517 9.64552	35	0.35483 0.35448	9.96129 9.96123	6	10	6 0.6 0.5 7 0.7 0.6
52	9.60704	29	9.64586	34	0.35414	9.96118	5	8	8 0.8 0.7
53	9.60732	28 29	9.64620	34 34	0.35380	9.96112	6	7	9 0.9 0.8
54	9.60761	29	9.64654	34 34	0.35346	9.96107	5 6	_6	10 1.0 0.8
55	9.60789	29	9.64688	34	0.35312	9.96101	6	5	20 2.0 1.7 30 3.0 2.5
56 57	9.60818 9.60846	28	9.64722 9.64756	34	0.35278 0.35244	9.96095 9.96090	5	3	40 4.0 3.3
58	9.60875	29	9.64790	34	0.35244	9.96090	6	2	50 5.0 4.2
59	9.60903	28	9.64824	34	0.35176	9.96079	5	ĩ	
60	9.60931	28	9.64858	34	0.35142	9.96073	6	0	ł
	L. Cos.	d.	L. Cotg.	d. c.	L.Tang.	L. Sin.	d.	-,-	P. P.

					24°					
′	L. Sin.	đ.	L.Tang.	d. c.	L. Cotg.	L. Cos.	d.		P.	P.
0	9.60931	29	9.64858	34	0.35142	9.96073	6	60		
1	9.60960	28	9.64892 9.64926	34	0.35108	9.96067 9.96062	5	59		
2 3	9.60988 9.61016	28	9.64960	34	0.35040	9.96056	6	58 57	34	33
4	9.61045	29	9.64994	34	0.35006	9.96050	6	56	6 3.4	
5	9.61073	28	9.65028	34	0.34972	9.96045	5	55	7 4.0 8 4.3	
6	9.61101	28 28	9.65062	34 34	0.34938	9.96039	· 6	54	9 5.	1 5.0
7	9.61129	29	9.65096	34	0.34904	9.96034	6	53	10 5.	7 5.
8 9	9.61158 9.61186	28	9.65130 9.65164	34	0.34870 0.34836	9.96028 9.96022	6	52 51	20 11.3 30 17.0	
10	9.61214	28	9.65197	33	0.34803	9.96017	5	50	40 22.	
ii	9.61242	28	9.65231	34	0.34769	9.96011	6	49	50 28.3	
12	9.61270	28 28	9.65265	34 34	0.34735	9.96005	6 5	48	-	
13	9.61298	28	9.65299	34	0.34701	9.96000	6	47		
14	9.61326	$\widetilde{28}$	9.65333	33	0.34667	9.95994	6	46	١	29
15 16	9.61354 9.61382	28	9.65366 9.65400	34	0.34634 0.34600	9.95988 9.95982	6	45 44	6	2.9 3.4
17	9.61411	29	9.65434	34	0.34566	9.95977	5	43	8	3.9
18	9.61438	27	9.65467	33	0.34533	9.95971	6	42	ğ	4.4
19	9.61466	28 28	9.65501	34 34	0.34499	9.95965	6 5	41	10	4.8
20	9.61494	28	9.65535	33	0.34465	9.95960	6	40	20 30 1	9.7 4.5
21 22	9.61522	28	9.65568	33 34	0.34432	9.95954	6	39		9.3
23	9.61550 9.61578	28	9.65602 9.65636	34	0.34398 0.34364	9.95948 9.95942	6	38 37		4.2
24	9.61606	28	9.65669	33	0.34331	9.95937	5	36	,	
25	9.61634	28	9.65703	34	0.34297	9.95931	6	35		
26	9.61662	28	9.65736	33	0.34264	9.95925	6	34		28
27	9.61689	27 28	9.65770	34 33	0.34230	9.95920	5 6	33	6	2.8
28 29	9.61717 9.61745	28	9.65803 9.65837	34	0.34197	9.95914	6	32 31		3.3 3.7
30	9.61743	28	9.65870	33	0.34163	9.95908	ő			4.2
31	9.61773	27	9.65904	34	0.34130 0.34096	9.95902 9.95897	5	30 29	10	4.7
32	9.61828	28	9.65937	33	0.34063	9.95891	6	28		9.3
33	9.61856	28 27	9.65971	34 33	0.34029	9.95885	6	27		1.0 3.7
34	9.61883	28	9.66004	34	0.33996	9.95879	6	26	50 2	3.3
35	9.61911	28	9.66038	33	0.33962	9.95873	5	25		
36 37	9.61939 9.61966	27	9.66071 9.66104	33	0.33929 0.33896	9.95868 9.95862	6	24 23		
38	9.61994	28	9.66138	34	0.33862	9.95856	6	22	2	7
39	9.62021	27	9.66171	33	0.33829	9.95850	6	21		.7
40	9.62049	28	9.66204	33	0.33796	9.95844	6	20		.2 .6
41	9.62076	27 28	9.66238	34 33	0.33762	9.95839	5	19		.1
42 43	9.62104 9.62131	27	9.66271 9.66304	33	0.33729	9.95833	6	18	10 4	.5
44	9.62131	28	9.66337	33	0.33696 0.33663	9.95827 9.95821	6	17 16	20 9	.0
45	9.62186	27	9.66371	34	0.33629	9.95815	6	15	30 13 40 18	
46	9.62214	28	9.66404	33	0.33596	9.95810	5	14	50 22	
47	9.62241	27 27	9.66437	33	0.33563	9.95804	6	13	,	
48	9.62268	28	9.66470	33 33	0.33530	9.95798	6	12		
49	9.62296	27	9.66503	34	0.33497	9.95792	6	11	6	5
50 51	9.62323 9.62350	27	9.66537	33	0.33463	9.95786	6	10,	6 0.6	0.5
52	9.62377	27	9.66570 9.66603	33	0.33430 0.33397	9.95780 9.95775	5	8	7 0.7 8 0.8	0.6
53	9.62405	28	9.66636	33	0.33364	9.95769	6	7	9 0.9	0.8
54	9.62432	27 27	9.66669	33 33	0.33331	9.95763	6	6	10 1.0	0.8
55	9.62459	27	9.66702	i	0.33298	9.95757		5	20 2.0	1.7
56 57	9.62486	27	9.66735	33 33	0.33265	9.95751	6	4	30 3.0 40 4.0	2.5 3.3
58	9.62513 9.62541	28	9.66768 9.66801	33	0.33232	9.95745 9.95739	6	3 2		4.2
59	9.62568	27	9.66834	33	0.33166	9.95733	6	í	55,570,	
60	9.62595	27	9.66867	33	0.33133	9.95728	5	-		
	L. Cos.	d.	L. Cotg.	d. c.	L.Tang.	L. Sin.	đ.	,	P. P.	
			·	u. c.	m. rang.	m. om.	u.			

,	L. Sin.	d.	L.Tang.	d. c.	L. Cotg.	L. Cos.	đ.	1 1	P. P.
0	9.62595		9.66867		0.33133	9.95728		60	
ĭ	9.62622	27	9.66900	33	0.33100	9.95722	6	59	
2	9.62649	27	9.66933	33	0.33067	9.95716	6	58	
3	9.62676	27	9.66966	33	0.33034	9.95710	6	57	33 32 6 3.3 3.2
4	9.62703	27	9.66999	33	0.33001	9.95704	6	56	$egin{array}{c c c c} 6 & 3.3 & 3.2 \\ 7 & 3.9 & 3.7 \\ \hline \end{array}$
5	9.62730	27	9.67032	33	0.32968	9.95698	6	55	8 4.4 4.3
6	9.62757	27	9.67065	33	0.32935	9.95692	6	54	9 5.0 4.8
7	9.62784	27	9.67098	33	0.32902	9.95686	6	53	10 5.5 5.3
8	9.62811	27	9.67131	33	0.32869	9.95680	6	52	20 11.0 10.7
9	9.62838	27	9.67163	32	0.32837	9.95674	6	51	30 16.5 16.0
10	9.62865	27	9.67196	33	0.32804	9.95668	6	50	40 22.0 21.3
ii	9.62892	27	9.67229	33	0.32771	9.95663	5	49	50 27.5 26.7
12	9.62918	26	9.67262	33	0.32738	9.95657	6	48	00 2110 2017
13	9.62945	27	9.67295	33	0.32705	9.95651	6	47	
14	9.62972	27	9.67327	32	0.32673	9.95645	6	46	
15	9.62999	27	9.67360	33	0.32640	9.95639	6		27 6 2.7
	9.63026	27	9.67393	33	0.32640	9.95633	6	45 44	
16 17	9.63052	26	9.67426	33	0.32574	9.95627	6	43	7 3.2 8 3.6
18	9.63079	27	9.67458	32	0.32542	9.95621	ě.	42	9 4.1
19	9.63106	27	9.67491	33	0.32509	9.95615	6	41	10 4.5
		27		33			6		20 9.0
20	9.63133	26	9.67524	32	0.32476	9.95609	6	40	30 13.5
21	9.63159	27	9.67556	33	0.32444	9.95603	6	39	40 18.0
22	9.63186	27	9.67589	33	0.32411	9.95597	6	38	50 22.5
23	9.63213	26	9.67622	32	0.32378	9.95591	6	37	00 22.0
24	9.63239	27	9.67654	33	0.32346	9.95585	6	36	
25	9.63266	26	9.67687	32	0.32313	9.95579		35	
26	9.63292	27	9.67719	33	0.32281	9.95573	6	34	26
27	9.63319	26	9.67752	33	0.32248	9.95567	6	33	6 2.6
28	9.63345	27	9.67785	32	0.32215	9.95561	6	32	7 3.0
29	9.63372	26	9.67817	33	0.32183	9.95555	6	31	8 3.5
30	9.63398		9.67850		0.32150	9.95549		30	9 3.9
31	9.63425	27	9.67882	32	0.32118	9.95543	6	29	10 4.3
32	9.63451	26	9.67915	33	0.32085	9.95537	6	28	20 8.7 30 13.0
33	9.63478	27	9.67947	32	0.32053	9.95531	6	27	
34	9.63504	26	9.67980	33	0.32020	9.95525	6	26	40 17.3 50 21.7
35	9.63531	27	9.68012	32	0.31988	9.95519	6	25	00 21.7
36	9.63557	26	9.68044	32	0.31956	9.95513	6	24	
37	9.63583	26	9.68077	33 32	0.31923	9.95507	6	23	i
38	9.63610	27	9.68109	32	0.31891	9.95500	7	22	11
39	9.63636	26	9.68142	33	0.31858	9.95494	6	21	6 0.7
40	9.63662	26	9.68174	32	0.31826	9.95488	6	20	7 0.8
41	9.63689	27	9.68206	32	0.31794	9.95482	6	19	8 0.9
42	9.63715	26	9.68239	33	0.31761	9.95476	6	18	9 1.1
43	9.63741	26	9.68271	32	0.31729	9.95470	6	17	10 1.2
44	9.63767	26	9.68303	32	0.31697	9.95464	6	16	20 2.3 30 3.5
45	9.63794	27	9.68336	33	0.31664	9.95458	6	15	30 3.5 40 4.7
46	9.63820	26	9.68368	32	0.31632	9.95458	6	14	50 5.8
47	9.63846	26	9.68400	32	0.31600	9.95446	6	13	0.0 0.0
48	9.63872	26	9.68432	32	0.31568	9.95440	6	12	
49	9.63898	26	9.68465	33	0.31535	9.95434	6	l ii l	
		26	9.68497	32	0.31503	9.95427	7		8 5
50	9.63924 9.63950	26	9.68497	32	0.31503	9.95427	6	10	6 0.6 0.5
51 52	9.63976	26	9.68561	32	0.31471	9.95421	ě	8	7 0.7 0.6
53 53	9.64002	26	9.68593	32	0.31407	9.95409	6	1 %	8 0.8 0.7
54	9.64028	26	9.68626	33	0.31374	9.95403	6	6	9 0.9 0.8 10 1.0 0.8
		26		32	I		6		$egin{array}{c c c c c c c c c c c c c c c c c c c $
55	9.64054	26	9.68658	32	0.31342	9.95397	6	5	30 3.0 2.5
56	9.64080	26	9.68690	32	0.31310	9.95391	7	4	40 4.0 3.3
57	9.64106	26	9.68722	32	0.31278	9.95384	6	3	50 5.0 4.2
58	9.64132	26	9.68754	32	0.31246	9.95378	6	2	00 0.0 4.2
59	9.64158	26	9.68786	32	0.31214	9.95372	ě	-	
60	9.64184		9.68818		0.31182	9.95366		0	
	L. Cos.	d.	L. Cotg.	d. c.	L.Tang.	L. Sin.	đ.	7	P. P.

					26°						
	L. Sin.	d.	L.Tang.	d. c.	L. Cotg.	L. Cos.	d.			P. P	-
0	9.64184 9.64210	26	9.68818 9.68850	32	0.31182 0.31150	9.95366 9.95360	6	60 59	1		
2	9.64236	26	9.68882	32	0.31118	9.95354	6	58	ĺ		
3	9.64262	26	9.68914	32	0.31086	9.95348	6	57	، ما	32	1 3
4	9.64288	26 25	9.68946	32 32	0.31054	9.95341	6	56	6 7	3.2 3.7	
5	9.64313		9.68978		0.31022	9.95335		55	8	4.3	
6	9.64339	26 26	9.69010	32 32	0.30990	9.95329	6	54	9	4.8	4
7	9.64365	26	9.69042	32	0.30958	9.95323	6	53	10	5.3	
8	9.64391 9.64417	26	9.69074 9.69106	32	0.30926	9.95317 9.95310	7	52 51	20	10.7	
		25	9.69138	32	0.30862	9.95304	6	50	30 40	16.0 21.3	
10 11	9.64442 9.64468	26	9.69170	32	0.30830	9.95298	6	49	50	26.7	
12	9.64494	26	9.69202	32	0.30798	9.95292	6	48	J		
13	9.64519	25	9.69234	32	0.30766	9.95286	6	47	l		
14	9.64545	26 26	9.69266	32 32	0.30734	9.95279	7	46	l	:	26
15	9.64571	25	9.69298	l	0.30702	9.95273		45	1		2.6
16	9.64596	26 26	9.69329	31 32	0.30671	9.95267	6	44	1		3.0
17	9.64622	25	9.69361 9.69393	32	0.30639 0.30607	9.95261 9.95254	7	43 42	1		3.5 3.9
18 19	9.64647 9.64673	26	9.69425	32	0.30575	9.90204	6	41	۱,		3.9 4.3
20	9.64698	25	9.69457	32	0.30543	9.95242	6	40			8.7
21	9.64724	26	9.69488	31	0.30512	9.95236	6	39	8	0 13	3.0
22	9.64749	25	9.69520	32	0.30480	9.95229	7	38			7.3
23	9.64775	26 25	9.69552	32 32	0.30448	9.95223	6	87	l °	0 2	1.7
24	9.64800	26	9.69584	31	0.30416	9.95217	6	36	ł		
25	9.64826	25	9.69615	32	0.30385	9.95211	7	85	I		
26	9.64851	26	9.69647	32	0.30353	9.95204	6	34 33	1		2.5 2.5
27 28	9.64877 9.64902	25	9.69679 9.69710	31	0.30321	9.95198 9.95192	6	82	l		2.9
29	9.64927	25	9.69742	32	0.30258	9.95185	7	81	l	8 3	3.3
30	9.64953	26	9.69774	32	0.30226	9.95179	6	30			3.8
31	9.64978	25	9.69805	31	0.30195	9.95173	6	29			1.2 3.3
32	9.65003	25 26	9.69837	32	0.30163	9.95167	6	28			2.5
33	9.65029	20 25	9.69868	31 32	0.30132	9.95160	6	27 26		0 16	3.7
34	9.65054	25	9.69900	32	0.30100	9.95154	6		5	0 20).8
35	9.65079	25	9.69932 9.69963	31	0.30068	9.95148 9.95141	7	25 24	1		
36 37	9.65104 9.65130	26	9.69995	32	0.30037	9.95141	6	23	ı		
38	9.65155	25	9.70026	31	0.29974	9.95129	6	22	1		4
39	9.65180	25	9.70058	32	0.29942	9.95122	7	21	[2.4 2.8
40	9.65205	25	9.70089	31	0.29911	9.95116	6	20	l		3.2
41	9.65230	25 25	9.70121	32 31	0.29879	9.95110	6 7	19			3.6
42	9.65255	20 26	9.70152	32	0.29848	9.95103	6	18			.0
43 44	9.65281 9.65306	25	9.70184 9.70215	31	0.29816 0.29785	9.95097 9.95090	7	17 16	1 2		3.0
		25	9.70213	32	0.29753	9.95084	6	15		0 12 0 16	2.0 i.0
45 46	9.65331 9.65356	25	9.70247	31	0.29753	9.95084	6	14		0 20	
47	9.65381	25	9.70309	31	0.29691	9.95071	7	13	ľ	- 1	-
48	9.65406	25	9.70341	32	0.29659	9.95065	6	12	l		
49	9.65431	25 25	9.70372	31 32	0.29628	9.95059	6	11		7	
50	9.65456		9.70404		0.29596	9.95052	6	10	6	0.7	0.6
51	9.65481	25 25	9.70435	31 31	0.29565	9.95046	7	9	7	0.8	0.7
52	9.65506	25	9.70466	32	0.29534	9.95039 9.95033	6	8 7	8	0.9	0.8
53 54	9.65531 9.65556	25	9.70498 9.70529	31	0.29502 0.29471	9.95033	6	6	10	1.1 1.2	1.0
~-		24	9.70560	31	0.29471	9.95020	7	5	20	2.3	2.0
55 56	9.65580 9.65605	25	9.70592	32	0.29440	9.95020	5	1 4	80	3.5	3.0
57	9.65630	25	9.70623	31	0.29377	9.95007	7	3	40	4.7	4.0
58	9.65655	25	9.70654	31	0.29346	9.95001	6	2	50	5.8	5.0
59	9.65680	25 25	9.70685	31 32	0.29315	9.94995	6 7	1	l		
60	9.65705	20	9.70717	02	0.29283	9.94988	'	0	1		
; I	L. Cos.	d.	L. Cotg.	d. c.	L.Tang.	L. Sin.	d.	7		P. P	•

' 1	L. Sin	. c	1.	L.Tang.	d. c.	L. Cotg.	L. Cos.	d.		P. P.
ō	9.6570	5		9.70717		0.29283	9.94988		60	
1 l	9.6572	9 2	24	9.70748	31	0.29252	9.94982	6	59	
2	9.6575		25	9.70779	31	0.29221	9.94975	7	58	
3	9.6577	9 }	25	9.70810	31	0.29190	9.94969	6	57	32 31 6 3.2 3.1
4	9.6580		25 24	9.70841	31 32	0.29159	9.94962	7	56	7 3.7 3.6
5	9.6582	× 1		9.70873		0.29127	9.94956		55	8 4.3 4.1
6	9.6585	3 3	25	9.70904	31	0.29096	9.94949	7	54	9 4.8 4.7
7	9.6587	O 1 7	25	9.70935	31	0.29065	9.94943	6 7 6	53	10 5.3 5.2
8	9.6590	- 1	24 25	9.70966	31 31	0.29034	9.94936	6	52	20 10.7 10.3
9	9.6592		25 25	9.70997	31	0.29003	9.94930	7	51	30 16.0 15.5
10	9.6595	21 .		9.71028		0.28972	9.94923		50	40 21.3 20.7
11	9.6597	U 1	24	9.71059	31	0.28941	9.94917	6	49	50 26.7 25.8
12	9.6600	- 1	25 24	9.71090	31	0.28910	9.94911	6 7 6 7	48	
13	9.6602		2 4 25	9.71121	31 32	0.28879	9.94904	6	47	
14	9.6605	0 8	25	9.71153	31	0.28847	9.94898	7	46	30
15	9.6607	.		9.71184		0.28816	9.94891		45	6 3.0
16	9.6609	, ,	24	9.71215	31	0.28785	9.94885	6	44	7 3.5
17	9.6612	~= ,	25	9.71246	31	0.28754	9.94878	7 7 6	43	8 4.0
18	9.6614	•	24 25	9.71277	31 31	0.28723	9.94871	1	42	9 4.5
19	9.6617		23 24	9.71308	31	0.28692	9.94865	7	41	10 5.0
20	9.6619	7 1		9.71339		0.28661	9.94858		40	20 10.0
21	9.6622		24	9.71370	31	0.28630	9.94852	6 7	39	30 15.0
22	9.6624		25	9.71401	31	0.28599	9.94845	7	38	40 20.0
23	9.6627	U 7	24	9.71431	30	0.28569	9.94839	6	37	50 25.0
24	9.6629		25	9.71462	31	0.28538	9.94832	7	36	
25	9.6631	9	24	9.71493	31	0.28507	9.94826	6	35	
26	9.6634		24	9.71524	31	0.28476	9.94819	7	34	25 24
27	9.6636	8 3	25	9.71555	31	0.28445	9.94813	6	33	6 2.5 2.4
28		74 7	24	9.71586	31	0.28414	9.94806	7 7	32	7 2.9 2.8
29	9.6641	16	24	9.71617	31	0.28383	9.94799	7	31	8 3.3 3.2
30	9.6644		25	9.71648	31	0.28352	9.94793	6	30	9 3.8 3.6
31		5 2	24	9.71679	31	0.28321	9.94786	7	29	10 4.2 4.0
32	9.6648	39 2	24	9.71709	30	0.28291	9.94780	6	28	20 8.3 8.0
33			24	9.71740	31	0.28260	9.94773	7	27	30 12.5 12.0
/ 34	l (9.6653		24	9.71771	31	0.28229	9.94767	^6	26	40 16.7 16.0
35	9.6656	52.1	25	9.71802	31	0.28198	9.94760	7	25	50 20.8 20.0
36		36 2	24	9.71833	31	0.28167	9.94753	7	24	
37		in 2	24	9.71863	30	0.28137	9.94747	6	23	
1 38			24	9.71894	31	0.28106	9.94740	7 6	$\widetilde{22}$	23
3	9 9.6668		24	9.71925	31	0.28075	9.94734	6	21	6 2.3
40	9.6668	K2 (24	9.71955	30	0.28045	9.94727	7	20	$7 \mid 2.7$
14		ns 2	24	9.71986	31	0.28014	9.94720	7	19	8 3.1
1 4	2 9.6673	31 2	25	9.72017	31	0.27983	9.94714	6	18	9 3.5
4	3 9.667	55 4	24	9.72048	31	0.27952	9.94707	7	17	10 3.8
4	4 9.667	79 2	24	9.72078	30	0.27922	9.94700	7	16	$egin{array}{c c} 20 & 7.7 \\ 30 & 11.5 \\ \hline \end{array}$
14	5 9.6680	133	24	9.72109	31	0.27891	9,94694	6	15	30 11.5 40 15.3
4	6 9.668	27 2	24	9.72140	31	0.27860	9.94687	7	14	50 19.2
4	7 9.668	51 2	24	9.72170	30	0.27830	9.94680	7	13	00 19.4
	8 9.668	75 2	24	9.72201	31	0.27799	9.94674	6 7 7	12	
4	9.6689	99 2	24	9.72231	30	0.27769	9.94667	7	liĩ	
5	9.669	29.1 -	23	9.72262	31	0.27738	9,94660		10	7 6
	9.669	16 2	24	9.72293	31	0.27707	9.94654	6	9	6 0.7 0.6 7 0.8 0.7
١,	2 9.669	70 2	24	9.72323	30	0.27677	9.94647	7	8	7 0.8 0.7 8 0.9 0.8
H	53 9.6699	94	24	9.72354	31	0.27646	9.94640	7 7 6 7	7	9 1.1 0.9
1 13	54 9.670	18 2	24	9.72384	30	0.27616	9.94634	6	6	10 1.2 1.0
1 17	55 9.670	49	24	9.72415	31	0.27585	9.94627		5	20 2.3 2.0
	56 \ 9.670	66	24	9.72445	30	0.27555	9.94620	7 6	4	30 3.5 3.0
	57 9.670	on l ≎	24	9.72476	31	0.27524	9.94614	6	3	40 4.7 4.0
	58 9.671°	13 2	23	9.72506	30	0.27494	9.94607	7	2	50 5.8 5.0
	59 9.671	37 3	24	9.72537	31	0.27463	9.94600	7 7 7	Ιĩ	- 1 1
17	9.971		24	9.72567	30	0.27433	9.94593	7	ô	
l F	L. Co		d.	L. Cotg.	d. c.	L.Tang,	L. Sin.	d.	-,'-	
-	· 111.00	70.	٠.	III. Cotg.	u. c.		1 12. 15111.	u.		P. P.
						62 °				

					28°				
	L. Sin.	d.	L.Tang.	d. c.	L. Cotg.	L. Cos.	d.	1	P. P.
0	9.67161	24	9.72567	31	0.27433	9.94593	0	60	
1 2	9.67185	23	9.72598	30	0.27402	9.94587	6	59	1
3	9.67208 9.67232	24	9.72628 9.72659	31	0.27372 0.27341	9.94580 9.94573	7	58 57	31 3
4	9.67256	24	9.72689	30	0.27311	9.94567	6 7	56	6 3.1 3
-5	9.67280	24	9.72720	31	0.27280	9.94560	7	55	7 3.6 3
6	9.67303	23	9.72750	30	0.27250	9.94553	7	54	8 4.1 4 9 4.7 4
7	9.67327	24	9.72780	30	0.27220	9.94546	7	53	10 5.2 5
8	9.67350	23 24	9.72811	31 30	0.27189	9.94540	6 7	52	20 10.3 10
9	9.67374	24	9.72841	31	0.27159	9.94533	7	51	30 15.5 15
10	9.67398	23	9.72872	30	0.27128	9.94526	7	50	40 20.7 20
11 12	9.67421 9.67445	24	9.72902 9.72932	30	0.27098 0.27068	9.94519		49 48	50 25.8 25
13	9.67468	23	9.72963	31	0.27037	9.94513 9.94506	6 7 7 7	47	
14	9.67492	24	9.72993	30	0.27007	9.94499	7	46	
15	9.67515	23	9.73023	30	0.26977	9.94492		45	6 2.9
16	9.67539	24	9.73054	31	0.26946	9.94485	7	44	7 3.4
17	9.67562	23 24	9.73084	30	0.26916	9.94479	6	43	8 3.9
18	9.67586	23	9.73114	30 30	0.26886	9.94472	7 7	42	9 4.4
19	9.67609	24	9.73144	31	0.26856	9.94465	7	41	10 4.8
20	9.67633	23	9.73175	30	0.26825	9.94458	7	40	20 9.7 30 14.5
21 22	9.67656 9.67680	24	9.73205 9.73235	30	0.26795	9.94451	6	39	40 19.3
23	9.67703	23	9.73265	30	0.26765 0.26735	9.94445 9.94438	7	38 37	50 24.2
24	9.67726	23	9.73295	30	0.26705	9.94431	7 7	36	
25	9.67750	24	9.73326	31	0.26674	9.94424	7	35	
26	9.67773	23	9.73356	30	0.26644	9.94417	7	34	24 23
27	9.67796	23 24	9.73386	30	0.26614	9.94410	7	33	6 2.4 2. 7 2.8 2
28	9.67820	23	9.73416	30 30	0.26584	9.94404	6 7	32	7 2.8 2
29	9.67843	23	9.73446	30	0.26554	9.94397	7	31	8 3.2 3. 9 3.6 3.
30	9.67866	24	9.73476	31	0.26524	9.94390	7	30	10 4.0 3.
31 32	9.67890 9.67913	23	9.73507 9.73537	30	0.26493 0.26463	9.94383 9.94376	7	29 28	20 8.0 7.
33	9.67936	23	9.73567	30	0.26433	9.94369	7	27	30 12.0 11.3
34	9.67959	23	9.73597	30	0.26403	9.94362	7	26	40 16.0 15.3
35	9.67982	23	9.73627	30	0.26373	9.94355	7	25	50 20.0 19.2
36	9.68006	24	9.73657	30	0.26343	9.94349	6	24	
37	9.68029	23 23	9.73687	30 30	0.26313	9.94342	7	23	
38	9.68052	23	9.73717	30	0.26283	9.94335	7	22	6 2.2
39	9.68075	23	9.73747	30	0.26253	9.94328	7	21	7 2.6
40	9.68098	23	9.73777	30	0.26223	9.94321		20	8 2.9
41 42	9.68121 9.68144	23	9.73807 9.73837	30	0.26193 0.26163	9.94314 9.94307	7 7 7	19 18	9 3.3
43	9.68167	23	9.73867	30	0.26133	9.94300	7	17	10 3.7
44	9.68190	23	9.73897	30	0.26103	9.94293	7	16	20 7.3 30 11.0
45	9.68213	23	9.73927	30	0.26073	9.94286	7	15	40 14.7
46	9.68237	24	9.73957	30	0.26043	9.94279	7	14	50 18.3
47	9.68260	23 23	9.73987	30 30	0.26013	9.94273	6	13	,
48	9.68283	22	9.74017	30	0.25983	9.94266	7	12	
49	9.68305	23	9.74047	30	0.25953	9.94259	7	11	7 8
50	9.68328	23	9.74077	30	0.25923	9.94252	7	10	6 0.7 0.6
51 52	9.68351 9.68374	23	9.74107 9.74137	30	0.25893 0.25863	9.94245 9.94238	7	9 8	7 0.8 0.7
53	9.68397	23 23	9.74166	29	0.25834	9.94231	7	9	8 0.9 0.8 9 1.1 0.9
54	9.68420	23	9.74196	30	0.25804	9.94224	7 7 7	6	9 1.1 0.9 10 1.2 1.0
55	9.68443	23	9.74226	30	0.25774	9.94217		5	20 2.3 2.0
56	9.68466	23	9.74256	30	0.25744	9.94210	7 7	4	30 3.5 3.0
57	9.68489	23 23	9.74286	30 30	0.25714	9.94203	7	3	40 4.7 4.0
58	9.68512 9.68534	22	9.74316	29	0.25684	9.94196	7	2	50 5.8 5.0
59		23	9.74345	30	0.25655	9.94189	7	1	
60	9.68557		9.74375		0.25625	9.94182		0	
	L. Cos.	đ.	L. Cotg.	d. c.	L.Tang.	L. Sin.	d.	7	P. P.

LOGARITHMS OF TRIGONOMETRIC FUNCTIONS.

′	L. Sin.	d.	L.Tang.	d. c.	L. Cotg.	L. Cos.	d.	l	P. P.
0	9.68557		9.74375		0.25625	9.94182		60	
ĭ	9.68580	23	9.74405	30	0.25595	9.94175	7	59	i
2	9.68603	23	9.74435	30	0.25565	9.94168	7 7	58	
3	9.68625	. 22	9.74465	30	0.25535	9.94161	7	57	30
4	9.68648	23	9.74494	29	0.25506	9.94154	7	56	6 3.0
5	9.68671	23	9.74524	30	0.25476	9.94147	7	55	7 3.5
6	9.68694	23	9.74554	30	0.25446	9.94140	7	54	8 4.0
7	9.68716	22	9.74583	29	0.25417	9.94133	7	53	9 4.5
8	9.68739	23	9.74613	30	0.25387	9.94126	7	52	10 5.0 20 10.0
ğ	9.68762	23	9.74643	30	0.25357	9.94119	7	51	
1		22		30			7		
10	9.68784	23	9.74673	29	0.25327	9.94112	7	50	40 20.0
11	9.68807	22	9.74702	30	0.25298	9.94105	7	49	50 25.0
12	9.68829	23	9.74732	30	0.25268	9.94098	8	48	
13	9.68852	23	9.74762	29	0.25238	9.94090	7	47	
14	9.68875	22	9.74791	30	0.25209	9.94083	7	46	29
15	9.68897		9.74821		0.25179	9.94076		45	6 2.9
16	9.68920	23	9.74851	30	0.25149	9.94069	7	44	7 3.4
17	9.68942	22	9.74880	29	0.25120	9.94062	7	43	8 3.9
18	9.68965	23	9.74910	30	0.25090	9.94055	7	42	9 4.4
19	9.68987	22	9.74939	29	0.25061	9.94048	7	41	10 4.8
20	9.69010	23	9.74969	30	0.25031	9.94041		40	20 9.7
21	9.69032	22	9.74998	29	0.25002	9.94034	7	39	30 14.5
22	9.69055	23	9.75028	30	0.24972	9.94027	7 7 7	38	40 19.3
23	9.69077	22	9.75058	30	0.24942	9.94020	7	37	50 24.2
24	9.69100	23	9.75087	29	0.24913	9.94012	8	36	'
		22		30			8 7		
25	9.69122	22	9.75117	29	0.24883	9.94005	7	35	23
26	9.69144	23	9.75146	30	0.24854	9.93998		34	
27	9.69167	$\widetilde{22}$	9.75176	29	0.24824	9.93991	7	33	6 2.3
28	9.69189	23	9.75205	30	0.24795	9.93984	÷	32	7 2.7
29	9.69212	22	9.75235	29	0.24765	9.93977	7	31	8 3.1 9 3.5
30	9.69234	22	9.75264		0.24736	9.93970		30	
31	9.69256	23	9.75294	30	0.24706	9.93963	7	29	$egin{array}{c c c} 10 & 3.8 \\ 20 & 7.7 \end{array}$
32	9.69279	22	9.75323	29	0.24677	9.93955	8	28	30 11.5
33	9.69301	22	9.75353	30	0.24647	9.93948	· '	27	40 15.3
34	9.69323	22	9.75382	29	0.24618	9.93941		26	50 19.2
35	9.69345		9.75411	29	0.24589	9.93934	7	25	00 15.2
36	9.69368	23	9.75441	30	0.24559	9.93927	7	24	
37	9.69390	22	9.75470	29	0.24530	9.93920	7	23	
38	9.69412	22	9.75500	30	0.24500	9.93912	8	$\widetilde{22}$	22
39	9.69434	22	9.75529	29	0.24471	9.93905	7	21	6 2.2
40	9.69456	22	9.75558	29	0.24442	9.93898	7	20	7 2.6
41	9.69479	23	9.75588	30	0.24412	9.93891	7	19	8 2.9
42	9.69501	22	9.75617	29	0.24383	9.93884	7	18	9 3.3
43	9.69523	22	9.75647	30	0.24353	9.93876	8	17	10 3.7
44	9.69545	22	9.75676	29	0.24324	9.93869	8 7 7	16	20 7.3
		22		29			7		30 11.0
45	9.69567	22	9.75705	30	0.24295	9.93862	7	15	40 14.7
46	9.69589	22	9.75735	29	0.24265	9.93855	8	14	50 18.3
47	9.69611	22	9.75764	29	0.24236	9.93847	7	13	
48		22	9.75793	29	0.24207	9 93840	7	12	
49		22	9.75822	30	0.24178	9.93833	7	_11	8 7
50	9.69677	22	9.75852	29	0.24148	9.93826	7	10	6 0.8 0.7
51		22 22	9.75881		0.24119	9.93819	8	9	7 0.9 0.8
52		22 22	9.75910	29 29	0.24090	9.93811	7	8	8 1.1 0.9
53		22	9.75939	30	0.24061	9.93804	7	7	9 1.2 1.1
54	9.69765	22	9.75969	29	0.24031	9.93797	8	6	10 1.3 1.2
55	9.69787		9.75998		0.24002	9.93789		5	20 2.7 2.3
56		22	9.76027	29	0.23973	9.93782	7	4	30 4.0 3.5
5		22	9.76056	29	0.23944	9.93775	7	3	40 5.3 4.7
58		22	9.76086	30	0.23914	9.93768	7	$\tilde{2}$	50 6.7 5.8
59		22	9.76115	29	0.23885	9.93760	8	ĩ	
80		22	9.76144	29	0.23856	9.93753	7	0	l
1-00				-				-	
<u> </u>	L. Cos.	d.	L. Cotg.	d.c.	L.Tang.	L. Sin.	d.	<u> </u>	P. P.

					30°				
′	L. Sin.	d.	L.Tang.	d. c.	L. Cotg.	L. Cos.	d.	1	P. P.
0	9.69897	22	9.76144	29	0.23856	9.93753	7	60	
1 2	9.69919 9.69941	22	9.76173 9.76202	29	0.23827 0.23798	9.93746		59	
1 3	9.69963	22	9.76231	29	0.23769	9.93738 9.93731	8 7	58 57	30 29
4	9.69984	21	9.76261	30	0.23739	9.93724	7	56	6 3.0 2.9 7 3.5 3.4
5	9.70006	22	9.76290	29	0.23710	9.93717	7	55	7 3.5 3.4 8 4.0 3.9
6	9.70028	22 22	9.76319	29 29	0.23681	9.93709	8	54	9 4.5 4.4
7 8	9.70050 9.70072	22	9.76348 9.76377	29	0.23652	9.93702	7 7 8	53	10 5.0 4.8
و	9.70093	21	9.76406	29	0.23623 0.23594	9.93695 9.93687	8	52 51	20 10.0 9.7 30 15.0 14.5
10	9.70115	22	9.76435	29	0.23565	9.93680	7	50	40 20.0 19.3
ii	9.70137	22	9.76464	29	0.23536	9.93673	7	49	50 25.0 24.2
12	9.70159	22 21	9.76493	29 29	0.23507	9.93665	8	48	
13 14	9.70180 9.70202	22	9.76522 9.76551	29	0.23478	9.93658	8	47	•
15	9.70202	22	9.76580	29	0.23449	9.93650	7	46	28
16	9.70245	21	9.76609	29	0.23420 0.23391	9.93643 9.93636	7	45 44	6 2.8 7 3.3
17	9.70267	22	9.76639	30	0.23361	9.93628	8	43	8 3.7
18	9.70288	21 22	9.76668	29 29	0.23332	9.93621	7 7	42	9 4.2
19	9.70310	22	9.76697	28	0.23303	9.93614	8	41	10 4.7
20 21	9.70332 9.70353	21	9.76725	29	0.23275	9.93606	7	40	20 9.3 30 14.0
22	9.70375	22	9.76754 9.76783	29	0.23246 0.23217	9.93599 9.93591	8	39 38	40 18.7
23	9.70396	21	9.76812	29	0.23188	9.93584	7 7	37	50 23.3
24	9.70418	22 21	9.76841	29 29	0.23159	9.93577	7 8	36	
25	9.70439	22	9.76870	29	0.23130	9.93569	7	35	
26 27	9.70461 9.70482	21	9.76899	29	0.23101	9.93562	8	34	6 2.2
28	9.70504	22	9.76928 9.76957	29	0.23072	9.93554 9.93547	7	33 32	7 2.6
29	9.70525	21	9.76986	29	0.23014	9.93539	8.	31	8 2.9
30	9.70547	22	9.77015	29	0.22985	9.93532	7	30	9 3.3
31	9.70568	21 22	9.77044	29 29	0.22956	9.93525	7 8	29	10 3.7 20 7.3
32 33	9.70590 9.70611	21	9.77073 9.77101	28	0.22927 0.22899	9.93517 9.93510	7	28	30 11.0
34	9.70633	22	9.77130	29	0.22870	9.93502	8	27 26	40 14.7
35	9.70654	21	9.77159	29	0.22841	9.93495		25	50 18.3
36	9.70675	21 22	9.77188	29	0.22812	9.93487	8	24	
37	9.70697	21	9.77217	29 29	0.22783	9.93480	7 8	23	21
1 38	9.70718 9.70739	21	9.77246 9.77274	28	$0.22754 \\ 0.22726$	9.93472 9.93465	7	22 21	6 2.1
40	9.70761	22	9.77303	29	0.22697	9.93457	8	20	7 2.5
41	9.70782	21	9.77332	29	0.22668	9.93450	7	19	8 2.8 9 3.2
42	9.70803	21 21	9.77361	29 29	0.22639	9.93442	8 7	18	9 3.2 10 3.5
43 44	9.70824 9.70846	22	9.77390	28	0.22610	9.93435	8	17	20 7.0
		$\overline{21}$	9.77418	29	0.22582	9.93427	7	16	30 10.5
45 46	9.70867 9.70888	21	9.77447 9.77476	29	$0.22553 \\ 0.22524$	9.93420 9.93412	8	15 14	40 14.0 50 17.5
47	9.70909	21	9.77505	29	0.22495	9.93405	7	13	00 17.0
48	9.70931	$\frac{22}{21}$	9.77533	28 29	0.22467	9.93397	8	12	
49	9.70952	21	9.77562	29	0.22438	9.93390	8	11	8 7
50	9.70973	21	9.77591	28	0.22409	9.93382	7	10	6 0.8 0.7.
51 52	9.70994 9.71015	21	9.77619 9.77648	29	0.22381 0.22352	9.93375 9.93367	8 7	9	7 0.9 0.8
53	9.71036	21	9.77677	29	0.22323	9.93360	7	7	$egin{array}{c c c c} 8 & 1.1 & 0.9 \\ 9 & 1.2 & 1.1 \\ \hline \end{array}$
54	9.71058	$\frac{22}{21}$	9.77706	29 28	0.22294	9.93352	8	6	10 1.3 1.2
55	9.71079	21	9.77734	29	0.22266	9.93344	7	5	20 2.7 2.3
56 57	9.71100 9.71121	21	9.77763	28	0.22237	9.93337	8	4	30 4.0 3.5 40 5.3 4.7
58	9.71121	21	9.77791 9.77820	29	0.22209 0.22180	9.93329 9.93322	7	3 2	40 5.3 4.7 50 6.7 5.8
59	9.71163	21	9.77849	29	0.22151	9.93314	8	î	25 51. 510
160	9.71184	21	9.77877	28	0.22123	9.93307	7	0	
	L. Cos.	d.	L. Cotg.	d. c.	L.Tang.	L. Sin.	d.	,	P. P.

					31°				
′	L. Sin.	d.	L.Tang.	d. c.	L. Cotg.	L. Cos.	d.		P. P.
0	9.71184	01	9.77877	00	0.22123	9.93307		60	
1	9.71205	21 21	9.77906	29 29	0.22094	9.93299	8	59	
2 3	9.71226 9.71247	21	9.77935 9.77963	28	0.22065	9.93291 9.93284	8 7	58 57	29
4	9.71268	21	9.77992	29	0.22008	9.93276	8	56	6 2.9
5	9.71289	21	9.78020	28	0.21980	9.93269	7	55	7 3.4
6	9.71310	21	9.78049	29	0.21951	9.93261	8	54	8 3.9 9 4.4
7	9.71331	21	9.78077	28	0.21923	9.93253	8	58	9 4.4 10 4.8
8	9.71352	21	9.78106	29	0.21894	9.93246	7	52	20 9.7
9	9.71373	21 20	9.78135	29 28	0.21865	9.93238	8	51	30 14.5
10	9.71393	21	9.78163	29	0.21837	9.93230		50	40 19.3
11	9.71414	21	9.78192	28	0.21808	9.93223	7 8	49	50 24.2
12	9.71435 9.71456	21	9.78220 9.78249	29	0.21780	9.93215		48	
13 14	9.71477	$\overline{21}$	9.78277	28	0.21751 0.21723	9.93207 9.93200	8 7	47 46	
15	9.71498	21	9.78306	29	0.21723		8	45	28
16	9.71519	21	9.78334	28	0.21666	9.93192 9.93184	8	44	6 2.8 7 3.3
17	9.71539	20	9.78363	29	0.21637	9.93177	7	43	8 3.7
18	9.71560	21	9.78391	28	0.21609	9.93169	8	42	9 4.2
19	9.71581	$\frac{21}{21}$	9.78419	28 29 ·	0.21581	9.93161	8	41	10 4.7
20	9.71602		9.78448		0.21552	9.93154		40	20 9.3
21	9.71622	20 21	9.78476	28 29	0.21524	9.93146	8	39	30 14.0
22	9.71643	21	9.78505	28	0.21495	9.93138	8	38	40 18.7 50 23.3
23 24	9.71664 9.71685	21	9.78533 9.78562	29	0.21467 0.21438	9.93131 9.93123	8	37 36	30 20.3
		20		28			8		
25	9.71705 9.71726	21	9.78590 9.78618	28	0.21410 0.21382	9.93115 9.93108	7	35	21
26 27	9.71747	21	9.78647	29	0.21353	9.93108	8	34	6 2.1
28	9.71767	20	9.78675	28	0.21325	9.93092	8	32	7 2.5
29	9.71788	21	9.78704	29	0.21296	9.93084	8 7	31	8 2.8
30	9.71809	21	9.78732	28	0.21268	9.93077		30	9 3.2
31	9.71829	20	9.78760	28	0.21240	9.93069	8	29	10 3.5
32	9.71850	21 20	9.78789	29 28	0.21211	9.93061	8	28	20 7.0 30 10.5
33	9.71870	21	9.78817 9.78845	28	0.21183	9.93053	7	27	40 14.0
34	9.71891	20		29	0.21155	9.93046	8	26	50 17.5
35	9.71911	21	9.78874	28	0.21126	9.93038	8	25	· •
36 37	9.71932 9.71952	20	9.78902 9.78930	28	0.21098 0.21070	9.93030 9.93022	8	24 23	
38	9.71973	21	9.78959	29	0.21041	9.93014	8	22	20
39	9.71994	21	9.78987	28	0.21013	9.93007		21	6 2.0
40	9.72014	20	9.79015	28	0.20985	9.92999	8	20	7 2.3
41	9.72034	20	9.79043	28	0.20957	9.92991	8	19	8 2.7 9 3.0
42	9.72055	21 20	9.79072	29 28	0.20928	9.92983	8	18	10 3.3
43	9.72075	21	9.79100	28	0.20900	9.92976	8	17	20 6.7
44	9.72096	20	9.79128	28	0.20872	9.92968	8	16	30 10.0
45 46	9.72116 9.72137	21	9.79156 9.79185	29	0.20844	9.92960	8	15	40 13.3
46	9.72137	20	9.79183	28	0.20815 0.20787	9.92952	8	14 13	50 16.7
48	9.72177	20	9.79241	28	0.20759	9.92944 9.92936	8	12	
49	9.72198	21	9.79269	28	0.20731	9.92929	7	iĩ	
50	9.72218	20	9.79297	28	0.20703	9.92921	8	10	$\begin{array}{ c c c c c c c c c c c c c c c c c c c$
51	9.72238	20	9.79326	29	0.20674	9.92913	8	9	$begin{array}{c c c} 6 & 0.8 & 0.7 \\ 7 & 0.9 & 0.8 \\ \hline \end{array}$
52	9.72259	21 20	9.79354	28 28	0.20646	9.92905	8	8	8 1.1 0.9
53	9.72279	20 20	9.79382	28 28	0.20618	9.92897	8	7	9 1.2 1.1
54	9.72299	21	9.79410	28	0.20590	9.92889	8	6	10 1.3 1.2
55	9.72320	20	9.79438	28	0.20562	9.92881	7	5	20 2.7 2.3
56	9.72340 9.72360	20	9.79466 9.79495	29	0.20534	9.92874	8	4	30 4.0 3.5 40 5.3 4.7
58	9.72381	21	9.79495	28	0.20505 0.20477	9.92866 9.92858	8	3 2	40 5.3 4.7 50 6.7 5.8
1 59	9.72401	20	9.79551	28	0.20477	9.92858	8	1	00 0.1 0.0
60	9,72421	20	9.79579	28	0.20421	9.92842	8	-	
1	L. Cos.	d.		d 0			- 3-	_,	
L	LTP. COR.	u.	L. Cotg.	d. c.	L.Tang.	L. Sin.	d.	'	P. P.

					32°							
7	L. Sin.	d.	L.Tang.	d. c.	L. Cotg.	L. Cos.	d.	Ī	1	P.	P.	
ō	9.72421		9.79579		0.20421	9.92842	_	60	_			
1 1	9.72441	20 20	9.79607	28 28	0.20393	9.92834	8	59	1			
3	9.72461 9.72482	21	9.79635 9.79663	28	0.20365 0.20337	9.92826 9.92818	8	58 57		2	B	28
4	9.72502	20	9.79691	28	0.20309	9.92810	8	56	6 7	2 3		2.8 3.3
5	9.72522	20	9.79719	28	0.20281	9.92803	7	55	8	3		3.7
6	9.72542	20	9.79747	28	0.20253	9.92795	8	54	Į š	4.	4	4.2
7	9.72562	20 20	9.79776	29 28	0.20224	9.92787	8	53	10	4.		4.7
8 9	9.72582 9.72602	20	9.79804 9.79832	28	0.20196 0.20168	9.92779 9.92771	8	52 51	20 30	9. 14.		9.3 4.0
10	9.72622	20	9.79860	28	0.20140	9.92763	8	50	40	19		8.7
lii	9.72643	21	9.79888	28	0.20112	9.92755	8	49	50	24.		23.3
12	9.72663	20 20	9.79916	28 28	0.20084	9.92747	8 8	48	1			
13	9.72683	20	9.79944	28	0.20056	9.92739	8	47 46				
14	9.72703	20	9.79972	$\widetilde{28}$	0.20028	9.92731	8	45	l		27 2.	- 1
15 16	9.72723 9.72743	20	9.80000 9.80028	28	0.20000 0.19972	9.92723 9.92715	8	44	l	6 7	3.	;
17	9.72763	20	9.80056	28	0.19944	9.92707	8	43	1	8	3.0	
18	9.72783	20 20	9.80084	28	0.19916	9.92699	8	42		9	4.	
19	9.72803	20	9.80112	28 28	0.19888	9.92691	8	41		10	4.	3
20	9.72823	20	9.80140	28	0.19860	9.92683	8	40		20 30	9.0 13.5	śΙ
21 22	9.72843 9.72863	20	9.80168 9.80195	27	0.19832 0.19805	9.92675 9.92667	8	39 38	ı	40	18.0	0
23	9.72883	20	9.80223	28	0.19777	9.92659	8	37	l	50	22.	5
24	9.72902	19 20	9.80251	28	0.19749	9.92651	8	36	l			- 1
25	9.72922		9.80279	28 28	0.19721	9.92643	8	35				l
26	9.72942	20 20	9.80307	28	0.19693	9.92635	8	34	6	21		20 2.0
27 28	9.72962 9.72982	20	9.80335 9.80363	28	0.19665 0.19637	9.92627 9.92619	8	33 32	1 7	2	5	2.3
29	9.73002	20	9.80391	28	0.19609	9.92611	8	31	- 8	2.	8	2.7
30	9.73022	20	9.80419	28	0.19581	9.92603	8	30	9	3.		3.0
31	9.73041	19 20	9.80447	28 27	0.19553	9.92595	8	29	10 20	3. 7.		3.3 6.7
32	9.73061	20	9.80474	28	0.19526	9.92587	8	28 27	30	10.	5 1	0.0
33 34	9.73081 9.73101	20	9.80502 9.80530	28	0.19498 0.19470	9.92579 9.92571	8	26	40	14.		3.3
35	9.73121	20	9.80558	28	0.19442	9.92563	8	25	50	17.	5 1	6.7
36	9.73140	19	9.80586	28	0.19414	9.92555	8	24				- 1
37	9.73160	20 20	9.80614	28 28	0.19386	9.92546	9 8	23	1		19	- 1
38	9.73180	20	9.80642 9.80669	27	0.19358 0.19331	9.92538 9.92530	8	22 21	l	6	1.9	
39 40	$\frac{9.73200}{9.73219}$	19	9.80697	28	0.19303	9.92522	8	20	ŀ	7	2.2	
41	9.73239	20	9.80697	28	0.19303	9.92522	8	19		8	2.5 2.9	ı
42	9.73259	20	9.80753	28	0.19247	9.92506	8	18	l	10	3.2	i
43	9.73278	19 20	9.80781	28 27	0.19219	9.92498	8	17		20	6.3	
44	9.73298	20	9.80808	28	0.19192	9.92490	8	16	l	30	9.5	
45 46	9.73318 9.73337	19	9.80836 9.80864	28	0.19164 0.19136	9.92482 9.92473	9	15 14		40 50	12.7 15.8	- 1
47	9.73357	20	9.80892	28	0.19108	9.92465	8	13		50	10.0	
48	9.73377	20	. 9.80919	27	0.19081	9.92457	8	12				
49	9.73396	19 20	9.80947	28 28	0.19053	9.92449	8	11	1	9	8	7
50	9.73416	19	9.80975	28	0.19025	9.92441	8	10	6	0.9	0.8	0.7
51	9.73435	20	9.81003 9.81030	27	0.18997 0.18970	9.92433 9.92425	8	8	7	1.1	0.9	0.8
52 53	9.73455 9.73474	19	9.81058	28	0.18942	9.92426	9	l [°] 7	8	1.2 1.4	1.1 1.2	0.9
54	9.73494	20	9.81086	28	0.18914	9.92408	8	6	10	1.5	1.3	1.2
55	9.73513	19	9.81113	27	0.18887	9.92400	8	5	20	3.0	2.7	1.2 2.3 3.5 4.7
56	9.73533	20 19	9.81141	28 28	0.18859	9.92392	8 8	4	30 40	4.5 6.0	4.0 5.3	3.5
57 58	9.73552 9.73572	20	9.81169 9.81196	27	0.18831 0.18804	9.92384 9.92376	8	3 2	50	7.5	6.7	5.8
59	9.73591	19	9.811224	28	0.18776	9.92367	9	í	ا ^ت '			, , ,
60	9.73611	20	9.81252	28	0.18748	9.92359	8	0	1			
-	L.Cos.	d.	L. Cotg.	d. c.	L.Tang.	L. Sin.	d.	- -		P.	P.	-
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LOGARITHMS OF TRIGONOMETRIC FUNCTIONS.

					33°				
7	L. Sin.	d.	L.Tang.	d. c.	L. Cotg.	L. Cos.	d.		P. P.
0	9.73611	19	9.81252	27	0.18748	9.92359	8	60	
1	9.73630	20	9.81279 9.81307	28	0.18721 0.18693	9.92351 9.92343	8	59 58	
3	9.73650 9.73669	1 9	9.81307	28	0.18665	9.92335	8	57	28 27
4	9.73689	20	9.81362	27	0.18638	9.92326	9	56	$egin{array}{ c c c c c c c c c c c c c c c c c c c$
5	9.73708	19	9.81390	28	0.18610	9.92318	8	55	7 3.3 3.2 8 3.7 3.6
6	9.73727	19	9.81418	28	0.18582	9.92310	8	54	9 4.2 4.1
7	9.73747	20 19	9.81445	27 28	0.18555	9.92302	8	53	10 4.7 4.5
8	9.73766	19	9.81473	27	0.18527	9.92293 9.92285	8	52	20 9.3 9.0
9	9.73785	20	9.81500	28	0.18500		8	51	30 14.0 13.5 40 18.7 18.0
10 11	9.73805 9.73824	19	9.81528 9.81556	28	0.18472 0.18444	9.92277 9.92269	8	50 49	50 23.3 22.5
12	9.73843	19	9.81583	27	0.18417	9.92260	9	48	
13	9.73863	20	9.81611	28	0.18389	9.92252	8	47	
14	9.73882	19 19	9.81638	27 28	0.18362	9.92244	8	46	20
15	9.73901	20	9.81666	27	0.18334	9.92235	8	45	6 2.0
16	9.73921	19	9.81693	28	0.18307	9.92227	8	44	7 2.3 8 2.7
17 18	9.73940 9.73959	19	9.81721 9.81748	$\widetilde{27}$	0.18279 0.18252	9.92219 9.92211	8	43	9 3.0
19	9.73978	19	9.81776	28	0.18224	9.92202	9	41	10 3.3
20	9.73997	19	9.81803	27	0.18197	9.92194	8	40	20 6.7
21	9.74017	20	9.81831	28	0.18169	9.92186	8	39	30 10.0
22	9.74036	19	9.81858	27 28	0.18142	9.92177	. 8	38	40 13.3 50 16.7
23	9.74055	19 19	9.81886	27	0.18114 0.18087	9.92169 9.92161	8	37	50 10.7
24	9.74074	19	9.81913	28			9	36	
25	9.74093 9.74113	20	9.81941 9.81968	27	0.18059 0.18032	9.92152 9.92144	8	35 34	19
26 27	9.74132	19	9.81996	28	0.18004	9.92136	8	33	6 1.9
28	9.74151	19	9.82023	27	0.17977	9.92127	9	32	7 2.2
29	9.74170	19 19	9.82051	28 27	0.17949	9.92119	8	31	8 2.5 9 2.9
30	9.74189	19	9.82078	28	0.17922	9.92111	9	30	$\begin{array}{c c} 9 & 2.9 \\ 10 & 3.2 \end{array}$
31	9.74208	19	9.82106	27	0.17894	9.92102	8	29	20 6.3
32 33	9.74227 9.74246	19	9.82133 9.82161	28	0.17867 0.17839	9.92094 9.92086	8	28 27	30 9.5
34	9.74265	19	9.82188	27	0.17812	9.92077	9	26	40 12.7
35	9.74284	. 19	9.82215	27	0.17785	9.92069	8	25	50 15.8
36	9.74303	19	9.82243	28	0.17757	9.92060	9	24	
37	9.74322	19 19	9.82270	27 28	0.17730	9.92052	8	23	18
38	9.74341 9.74360	19	9.82298 9.82325	27	0.17702 0.17675	9.92044 9.92035	9	22 21	6 1.8
39	9.74379	19	9.82352	27	0.17648	9.92033	8		7 2.1
40 41	9.74379	19	9.82352	28	0.17648	9.92027	9	20 19	8 2.4
42	9.74417	19	9.82407	27	0.17593	9.92010	8	18	9 2.7 10 3.0
43	9.74436	19	9.82435	28	0.17565	9.92002	8	17	20 6.0
44	9.74455	19 19	9.82462	27 27	0.17538	9.91993	8	16	30 9.0
45	9.74474	19	9.82489	28	0.17511	9.91985	9	15	40 12.0
46 47	9.74498 9.74512	19	9.82517 9.82544	27	0.17483 0.17456	9.91976 9.91968	8	14 13	50 15.0
47	9.74512	19	9.82571	27	0.17436	9.91908	9	12	·
49	9.74549	18	9.82599	28	0.17401	9.91951	8	11	9 8
50	9.74568	19	9.82626	27	0.17374	9.91942	9	10	6 0.9 0.8
51	9.74587	19 19	9.82653	27 28	0.17347	9.91934	8 9	9	7 1.1 0.9
52	9.74606	19	9.82681	28 27	0.17319	9.91925	8	8	8 1.2 1.1
53 54	9.74625 9.74644	19	9.82708 9.82735	27	0.17292 0.17265	9.91917 9.91908	9	7	9 1.4 1.2
$\frac{54}{55}$	9.74662	18	9.82762	27	0.17238	9.91900	8	- 5	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
56	9.74662	19	9.82762	28 27	0.17238	9.91900	9	4	30 4.5 4.0
56 57	9.74700	19	9.82817	27	0.17183	9.91883	8	3	40 6.0 5.3
58	9.74719	19 18	9.82844	27 27	0.17156	9.91874	9 8	2	50 7.5 6.7
59	9.74737	19	9.82871	28	0.17129	9.91866	ŝ	_1_	
60	9.74756		9.82899		0.17101	9.91857		0	
	L. Cos.	d.	L. Cotg.	d. c.	L.Tang.	L. Sin.	d.	1	P. P.

					34°				
7	L. Sin.	d.	L.Tang.	d. c.	L. Cotg.	L. Cos.	d.		P. P.
0	9.74756	19	9.82899	27	0.17101	9.91857	8	60	
1	9.74775	19	9.82926 9.82953	27	0.17074 0.17047	9.91849 9.91840	9	59 58	
3	9.74794 9.74812	18	9.82980	27	0.17020	9.91832	8	57	28 27
4	9.74831	19	9.83008	28	0.16992	9.91823	9	56	6 2.8 2.7 7 3.3 3.2
5	9.74850	19	9.83035	27	0.16965	9.91815	8	55	8 3.7 3.6
6	9.74868	18	9.83062	27	0.16938	9.91806	9	54	9 42 41
7	9.74887	19 19	9.83089	27 28	0.16911	9.91798	8	53	10 4.7 4.5
1 8	9.74906	18	9.83117	27	0.16883	9.91789	8	52 51	20 9.3 9.0
9	9.74924	19.	9.83144	27	0.16856	9.91781	ğ		30 14.0 13.5 40 18.7 18.0
10	9.74943	18	9.83171	27	0.16829 0.16802	9.91772 9.91763	9	50 49	40 18.7 18.0 50 23.3 22.5
11 12	9.74961 9.74980	19	9.83198 9.83225	27	0.16775	9.91755	8	48	00 20.0 22.0
13	9.74999	19	9.83252	27	0.16748	9.91746	9	47	
14	9.75017	18	9.83280	28	0.16720	9.91738	8	46	26
15	9.75036	19	9.83307	27	0.16693	9.91729	9	45	6 2.6
16	9.75054	18	9.83334	27	0.16666	9.91720	9	44	7 3.0
17	9.75073	19 18	9.83361	27 27	0.16639	9.91712	8	43	8 3.5
18	9.75091	19	9.83388	27	0.16612 0.16585	9.91703	8	42 41	9 3.9 10 4.3
19	9.75110	18	9.83415	27		9.91695	ğ		20 8.7
20	9.75128	19	9.83442 9.83470	28	0.16558 0.16530	9.91686 9.91677	9	40 39	30 13.0
21 22	9.75147 9.75165	18	9.83470	27	0.16503	9.91669	8	38	40 17.3
23	9.75184	19	9.83524	27	0.16476	9.91660	9	37	50 21.7
24	9.75202	18	9.83551	27 27	0.16449	9.91651	9	36	
25	9.75221	19	9.83578		0.16422	9.91643	8	35	
26	9.75239	18 19	9.83605	27 27	0.16395	9.91634	9	34	19
27	9.75258	18	9.83632	27	0.16368	9.91625	8	33	6 1.9 7 2.2
28	9.75276	18	9.83659 9.83686	27	0.16341 0.16314	9.91617 9.91608	ğ	32 31	8 25
29	9.75294	19		27			9		9 2.9
30	9.75313	18	9.83713 9.83740	27	0.16287 0.16260	9.91599 9.91591	8	30 29	10 3.2
31 32	9.75331 9.75350	19	9.83768	28	0.16232	9.91582	9	28	20 6.3
33	9.75368	18	9.83795	27	0.16205	9.91573	9	27	30 9.5
34	9.75386	18 19	9.83822	27 27	0.16178	9.91565	8	26	40 12.7 50 15.8
35	9.75405		9.83849		0.16151	9.91556		25	00 10.0
36	9.75423	18 18	9.83876	27 27	0.16124	9.91547	9	24	•
37	9.75441	18	9.83903	27	0.16097	9.91538	8	23 22	18
38 39	9.75459	19	9.83930 9.83957	27	0.16070 0.16043	9.91530 9.91521	ğ	21	6 1.8
	9.75478	18		27			9	20	7 2.1
40	9.75496 9.75514	18	9.83984 9.84011	27	0.16016 0.15989	9.91512 9.91504	8	19	8 2.4
42	9.75533	19	9.84038	27	0.15962	9.91495	9	18	9 2.7 10 3.0
43	9.75551	18	9.84065	27	0.15935	9.91486	9	17	20 6.0
44	9.75569	18 18	9.84092	27 27	0.15908	9.91477	9 8	16	30 9.0
45	9.75587		9.84119		0.15881	9.91469	9	15	40 12.0
46	9.75605	18 19	9.84146	27 27	0.15854	9.91460	9	14	50 15.0
47	9.75624	18	9.84173	27	0.15827	9.91451	9	13 12	l
48 49	9.75642 9.75660	18	9.84200 9.84227	27	0.15800 0.15773	9.91442 9.91433	9	11	
		18	9.84254	27	0.15746	9.91425	8	10	9 8
50 51	9.75678 9.75696	18	9.84234 9.84280	26	0.15746	9.91425	9	9	6 0.9 0.8 7 1.1 0.9
52	9.75714	18	9.84307	27	0.15693	9.91407	9	8	8 1.2 1.1
53	9.75733	19	9.84334	27 27	0.15666	9.91398	9	7	9 1.4 1.2
54	9.75751	18 18	9.84361	27	0.15639	9.91389	. 8	6	10 1.5 1.3
55	9.75769	18	9.84388	27	0.15612	9.91381	9	5	20 3.0 2.7
56	9.75787	18	9.84415	27	0.15585	9.91372	9	3	30 4.5 4.0 40 6.0 5.3
57 58	9.75805 9.75823	18	9.84442 9.84469	27	0.15558 0.15531	9.91363 9.91354	9	2	50 7.5 6.7
59	9.75841	18	9.84496	27	0.15504	9.91345	9	î	
50	9.75859	18	9.84523	27	0.15477	9.91336	9	0	
	L. Cos.	<u>d</u> .	L. Cotg.	d. c.	L. Tang.	L. Sin.	d.	,	P. P.
-	. D. OUS.	ч.	in. Oorg.	u. U.	m. rang.	D. OIII.	4.		'

LOGARITHMS OF TRIGONOMETRIC FUNCTIONS.

					35°				
7	L. Sin.	d.	L.Tang.	d. c.	L. Cotg.	L. Cos.	d.		P. P.
0	9.75859	10	9.84523	0.7	0.15477	9.91336		60	
1	9.75877	18 18	9.84550	27 26	0.15450	9.91328	8	59	
3	9.75895 9.75913	18	9.84576 9.84603	27	0.15424 0.15397	9.91319 9.91310	ğ	58 57	27 26
4	9.75931	18	9.84630	27	0.15370	9.91301	9	56	6 2.7 2.6
5	9.75949	18	9.84657	27	0.15343	9.91292	9	55	7 3.2 3.0 8 3.6 3.5
6	9.75967	18	9.84684	27	0.15316	9.91283	9	54	9 4.1 3.9
7	9.75985	18 18	9.84711	27 27	0.15289	9.91274	9	53	10 4.5 4.3
8	9.76003	18	9.84738	26	0.15262	9.91266	8	52	20 9.0 8.7
9	9.76021	18	9.84764	27	0.15236	9.91257	9	51	30 13.5 13.0 40 18.0 17.3
10	9.76039 9.76057	18	9.84791 9.84818	27	0.15209 0.15182	9.91248 9.91239	9	50 49	40 18.0 17.3 50 22.5 21.7
11 12	9.76075	18	9.84845	27	0.15155	9.91239	9	48	00 22.0 22.7
13	9.76093	18	9.84872	27	0.15128	9.91221	9	47	
14	9.76111	18 18	9.84899	27 26	0.15101	9.91212	9	46	18
15	9.76129		9.84925		0.15075	9.91203	9	45	6 1.8
16	9.76146	17 18	9.84952	27 27	0.15048	9.91194	9	44	7 2.1
17 18	9.76164 9.76182	18	9.84979 9.85006	27	0.15021 0.14994	9.91185 9.91176	9	43 42	8 2.4 9 2.7
19	9.76200	18	9.85033	27	0.14967	9.91167	9	41	10 3.0
20	9.76218	18	9.85059	26	0.14941	9.91158	9	40	20 6.0
21	9.76236	18	9.85086	27	0.14914	9.91149	9	39	30 9.0
22	9.76253	17	9.85113	27	0.14887	9.91141	8	38	40 12.0 50 15.0
23	9.76271	18 18	9.85140	27 26	0.14860	9.91132	9	37	50 15.0
24_	9.76289	18	9.85166	27	0.14834	9.91123	9	36	
25	9.76307	17	9.85193	27	0.14807	9.91114	9	35 34	17
26 27	9.76324 9.76342	18	9.85220 9.85247	27	0.14780 0.14753	9.91105 9.91096	9	33	6 1.7
28	9.76360	18	9.85273	26	0.14727	9.91087	9	32	7 2.0
29	9.76378	18 17	9.85300	27	0.14700	9.91078	9	31	8 2.3
30	9.76395		9.85327	27	0.14673	9.91069		30	9 2.6 10 2.8
31	9.76413	18 18	9.85354	27 26	0.14646	9.91060	9	29	20 5.7
32 33	9.76431 9.76448	17	9.85380 9.85407	27	0.14620 0.14593	9.91051 9.91042	9	28 27	30 8.5
34	9.76466	18	9.85434	27	0.14566	9.91033	9	26	40 11.3
35	9.76484	18	9.85460	26	0.14540	9.91023	10	25	50 14.2
36	9.76501	17	9.85487	27	0.14513	9.91014	9	24	
37	9.76519	18 18	9.85514	27 26	0.14486	9.91005	9	23	10
38	9.76537	17	9.85540	20	0.14460	9.90996	9	22	6 1.0
39	9.76554	18	9.85567	27	0.14433	9.90987	9	21	7 1.2
40 41	9.76572 9.76590	18	9.85594 9.85620	26	0.14406 0.14380	9.90978 9.90969	9	20 19	8 1.3
42	9.76607	17	9.85647	27	0.14353	9.90960	9	18	9 1.5 10 1.7
43	9.76625	18	9.85674	27	0.14326	9.90951	9	17	20 3.3
44	9.76642	17 18	9.85700	26 27	0.14300	9.90942	9	16	30 5.0
45	9.76660	17	9.85727	27	0.14273	9.90933	9	15	40 6.7
46	9.76677	18	9.85754	26	0.14246	9.90924 9.90915	9	14 13	50 8.3
47 48	9.76695 9.76712	17	9.85780 9.85807	27	0.14220 0.14193	9.90915	9	12	
49	9.76730	18	9.85834	27	0.14166	9.90896	10	iĩ	9 8
50	9.76747	17	9.85860	26	0.14140	9.90887	9	10	9 8 6 0.9 0.8
51	9.76765	18	9.85887	27	0.14113	9.90878	9	9	7 1.1 0.9
52	9.76782	17 18	9.85913	26 27	0.14087	9.90869	9	8	8 1.2 1.1
53	9.76800 9.76817	17	9.85940	27	0.14060	9.90860 9.90851	9	7	9 1.4 1.2
_		18	9.85967	26			9	$\frac{6}{5}$	$egin{array}{c c c c c c c c c c c c c c c c c c c $
55 56	9.76835 9.76852	17	9.85993 9.86020	• 27	0.14007 0.13980	9.90842 9.90832	10	4	30 4.5 4.0
57	9.76870	18	9.86046	26	0.13954	9.90823	9	3	40 6.0 5.3
58	9.76887	17	9.86073	27	0.13927	9.90814	9	2	50 7.5 6.7
59	9.76904	17 18	9.86100	27 26	0.13900	9.90805	9	_1	
60	9.76922	10	9.86126		0.13874	9.90796		0	
	L. Cos.	d.	L. Cotg.	d. c.	L. Tang.	L. Sin.	d.	,	P. P.

					36°				
1	L. Sin.	d.	L.Tang.	d. c.	L. Cotg.	L. Cos.	d.		P. P.
0	9.76922	17	9.86126	27	0.13874	9.90796	9	60	
1 1	9.76939	18	9.86153	26	0.13847 0.13821	9.90787 9.90777	10	59 58	
2 3	9.76957 9.76974	17	9.86179 9.86206	27	0.13794	9.90768	9	57	27 26
4	9.76991	17	9.86232	26 27	0.13768	9.90759	9	56	$egin{array}{ c c c c c c c c c c c c c c c c c c c$
5	9.77009	18	9.86259		0.13741	9.90750	9	55	8 3.6 3.5
6	9.77026	17 17	9.86285	26 27	0.13715	9.90741	10	54	9 4.1 3.9
8	9.77043 9.77061	18	9.86312 9.86338	26	0.13688 0.13662	9.90731 9.90722	9	53 52	10 4.5 4.3 20 9.0 8.7
9	9.77078	17	9.86365	27	0.13635	9.90713	9	51	30 13.5 13.0
10	9.77095	17	9.86392	27	0.13608	9.90704	9	50	40 18.0 17.3
11	9.77112	17 18	9.86418	26 27	0.13582	9.90694	10 9	49	50 22.5 21.7
12 13	9.77130 9.77147	17	9.86445 9.86471	26	0.13555 0.13529	9.90685 9.90676	9	48 47	
14	9.77164	17	9.86498	27	0.13502	9.90667	9	46	18
15	9.77181	17	9.86524	26	0.13476	9.90657	10	45	6 1.8
16	9.77199	18 17	9.86551	27 26	0.13449	9.90648	9	44	7 2.1
17	9.77216	17	9.86577	26 26	0.13423	9.90639 9.90630	9	43 42	$\begin{array}{c c} 8 & 2.4 \\ 9 & 2.7 \end{array}$
18 19	9.77233 9.77250	17	9.86603 9.86630	27	0.13397 0.13370	9.90620	10	41	10 3.0
20	9.77268	18	9.86656	26	0.13344	9.90611	9	40	20 6.0
21	9.77285	17	9.86683	27	0.13317	9.90602	9 10	39	30 9.0 40 12.0
22	9.77302	17 17	9.86709	26 27	0.13291	9.90592 9.90583	9	38	50 15.0
23 24	9.77319 9.77336	1 7	9.86736 9.86762	26	0.13264 0.13238	9.90574	9	37 36	00 20.0
$\frac{24}{25}$	9.77353	17	9.86789	27	0.13211	9.90565	9	35	
26	9.77370	17	9.86815	26	0.13185	9.90555	10	34	17
27	9.77387	17 18	9.86842	27 26	0.13158	9.90546	9	33	6 1.7 7 2.0
28	9.77405	17	9.86868	26	0.13132 0.13106	9.90537 9.90527	10	32 31	$\begin{array}{c c} 7 & 2.0 \\ 8 & 2.3 \end{array}$
29	$\frac{9.77422}{9.77439}$	17	9.86894	27	0.13079	9.90518	9	30	9 2.6
30 31	9.77456	17	9.86947	26	0.13079	9.90509	9	29	10 2.8
32	9.77473	17 17	9.86974	27	0.13026	9.90499	10 9	28	20 5.7 30 8.5
33	9.77490	17	9.87000	$\frac{26}{27}$	0.13000	9.90490	10	27	40 11.3
34	9.77507	Ĩ7	9.87027	26	0.12973	9.90480	9	26	50 14.2
35	9.77524 9.77541	17	9.87053 9.87079	26	0.12947	9.90462	9	25 24	
36	9.77558	17	9.87106	27	0.12894	9.90452	10	23	
38	9.77575	17 17	9.87132	26 26	0.12868	9.90443	9	22	6 1.6
39	9.77592	17	9.87158	27	0.12842	9.90434	10	21	7 1.9
40	9.77609 9.77626	17	9.87185 9.87211	26	0.12815 0.12789	9.90424 9.90415	9	20 19	8 2.1
41 42	9.77643	17	9.87238	27	0.12762	9.90405	10	18	9 2.4 10 2.7
43	9.77660	17 17	9.87264	26 26	0.12736	9.90396	9 10	17	20 5.3
44	9.77677	17	9.87290	26 27	0.12710	9.90386	9	16	30 8.0
45	9.77694	17	9.87317	26	0.12683 0.12657	9.90377 9.90368	9	15 14	40 10.7 50 13.3
46 47	9.77711 9.77728	17	9.87343 9.87369	26	0.12637	9.90358	10	13	90 15.5
48	9.77744	16	9.87396	27	0.12604	9.90349	9	12	
49	9.77761	17 17	9.87422	$\frac{26}{26}$	0.12578	9.90339	10	11	10 9
50	9.77778	17	9.87448	27	0.12552	9.90330	10	10	6 1.0 0.9
51	9.77795 9.77812	17	9.87475 9.87501	26	0.12525 0.12499	9.90320 9.90311	9	9	$egin{array}{c c c c c c c c c c c c c c c c c c c $
52 53	9.77829	17	9.87527	26	0.12433	9.90301	10	7	9 1.5 1.4
54	9.77846	17 16	9.87554	27 26	0.12446	9.90292	9 10	6	10 1.7 1.5
55	9.77862	17	9.87580	26	0.12420	9.90282	9	5	20 3.3 3.0 30 5.0 4.5
56	9.77879 9.77896	17	9.87606 9.87633	27	$0.12394 \\ 0.12367$	9.90273 9.90263	10	3	30 5.0 4.5 40 6.7 6.0
57 58	9.77913	17	9.87659	26	0.12367	9.90254	9	2	50 8.3 7.5
59	9.77930	17 16	9.87685	26 26	0.12315	9.90244	10 9	ī	
0	9.77946	10	9.87711	20	0.12289	9.90235	9	0	
-	L. Cos.	d.	L. Cotg.	d. c.	L.Tang.	L. Sin	d.	,	P. P.

					37°				
•	L. Sin.	đ.	L.Tang.	d. c.	L. Cotg.	L. Cos.	d.		P. P.
0	9.77946	177	9.87711	07	0.12289	9.90235	10	60	
1	9.77963	17 17	9.87738	27 26	0.12262	9.90225	10 9	59	
2 3	9.77980 9.77997	17	9.87764 9.87790	26	0.12236 0.12210	9.90216 9.90206	10	58 57	27
4	9.78013	16	9.87817	27	0.12183	9.90197	9	56	$\begin{array}{c c} 6 & 2.7 \\ 7 & 3.2 \end{array}$
5	9.78030	17	9.87843	26	0.12157	9.90187	10	55	7 3.2 8 3.6
6	9.78047	17	9.87869	26 26	0.12131	9.90178	9	54	9 4.1
7	9.78063	16 17	9.87895	27	0.12105	9.90168	10 9	53	10 4.5
8	9.78080 9.78097	17	9.87922 9.87948	26	0.12078 0.12052	9.90159 9.90149	10	52 51	20 9.0 30 13.5
10	9.78113	16	9.87974	26	0.12026	9.90139	10	50	40 18.0
ii	9.78130	17	9.88000	26	0.12000	9.90130	9	49	50 22.5
12	9.78147	17	9.88027	27 26	0.11973	9.90120	10	48	•
13	9.78163	16 17	9.88053	26 26	0.11947	9.90111 9.90101	9 10	47	
14	9.78180	17	9.88079	26	0.11921		10	46	26
15 16	9.78197 9.78213	16	9.88105 9.88131	26 27	0.11895 0.11869	9.90091 9.90082	9	45 44	$\begin{array}{c c} 6 & 2.6 \\ 7 & 3.0 \end{array}$
1 17	9.78230	17	9.88158	27	0.11842	9.90072	10	43	8 3.5
18	9.78246	16	9.88184	26 26	0.11816	9.90063	9	42	9 3.9
19	9.78263	17 17	9.88210	26	0.11790	9.90053	10 10	41	10 4.3
20	9.78280	16	9.88236	26	0.11764	9.90043	9	40	20 8.7 30 13.0
21 22	9.78296 9.78313	17	9.88262 9.88289	27	0.11738 0.11711	9.90034 9.90024	10	39 38	40 17.3
23	9.78329	16	9.88315	26	0.11685	9.90014	10	37	50 21.7
24	9.78346	17	9.88341	26 26	0.11659	9.90005	9	36	
25	9.78362	16	9.88367	26	0.11633	9.89995	10	35	
26	9.78379	17 16	9.88393	27	0.11607	9.89985	10 9	34	6 1.7
27 28	9.78395 9.78412	17	9.88420 9.88446	26	0.11580 0.11554	9.89976 9.89966	10	33 32	$\begin{array}{c c} 6 & 1.7 \\ 7 & 2.0 \end{array}$
29	9.78428	16	9.88472	26	0.11528	9.89956	10	31	8 2.3
30	9.78445	17	9.88498	26	0.11502	9.89947	9	30	9 2.6
31	9.78461	16	9.88524	26 26	0.11476	9.89937	10	29	10 2.8 20 5.7
32	9.78478	17 16	9.88550	27	0.11450	9.89927	10 9	28	30 8.5
33 34	9.78494 9.78510	16	9.88577 9.88603	26	0.11423 0.11397	9.89918 9.89908	10	27 26	40 11.3
35	9.78527	17	9.88629	26	0.11371	9.89898	10	25	50 14.2
36	9.78543	16	9.88655	26	0.11345	9.89888	10	24	
37	9.78560	17 16	9.88681	26 26	0.11319	9.89879	9 10	23	16
38	9.78576 9.78592	16	9.88707 9.88733	26	0.11293 0.11267	9.89869 9.89859	10	22 21	6 1.6
-	9.78609	17	9.88759	26	0.11241	9.89849	10		7 1.9
40 41	9.78625	16	9.88786	27	0.11214	9.89840	9	20 19	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
42	9.78642	17	9.88812	26 26	0.11188	9.89830	10	18	9 2.4 10 2.7
43	9.78658	16 16	9.88838	26	0.11162	9.89820	10 10	17	20 5.3
44	9.78674	17	9.88864	26	0.11136	9.89810	9	16	30 8.0
45 46	9.78691 9.78707	16	9.88890 9.88916	26	0.11110 0.11084	9.89801 9.89791	10	15 14	40 10.7 50 13.3
47	9.78723	16	9.88942	26	0.11058	9.89781	10	13	00 10.0
48		16 17	9.88968	26 26	0.11032	9.89771	10 10	12	
49	_	16	9.88994	26	0.11006	9.89761	9	11	10 9
50	9.78772	16	9.89020	26	0.10980	9.89752	10	10	6 1.0 0.9
51 52		17	9.89046 9.89073	27	0.10954 0.10927	9.89742 9.89732	iŏ	8	$egin{array}{c c c c c c c c c c c c c c c c c c c $
53	9.78821	16	9.89099	26	0.10901	9.89722	10	7	9 1.5 1.4
54		16 16	9.89125	26 26	0.10875	9.89712	10 10	_6_	10 1.7 1.5
55		16	9.89151	26	0.10849	9.89702	9	5	20 3.3 3.0
56 57		17	9.89177	26	0.10823	9.89693 9.89683	10	4 3	30 5.0 4.5 40 6.7 6.0
58		16	9.89203	26	0.10797	9.89673	10	2	50 8.3 7.5
59	9.78918	16	9.89255	26 26	0.10745	9.89663	10	ĩ	
60	9.78934	16	9.89281	20	0.10719	9.89653	10	0	
	L. Cos.	d.	L. Cotg.	d. c.	L.Tang.	L. Sin.	d.	- -	P. P.

					38°				
	L. Sin.	d.	L.Tang.	d. c.	L. Cotg.	L. Cos.	d.		P. P.
0	9.78934 9.78950	16	9.89281 9.89307	26	0.10719 0.10693	9.89653 9.89643	10	60	
2	9.78967	17	9.89333	26	0.10667	9.89633	10	59 58	
2 3	9.78983	16	9.89359	26	0.10641	9.89624	19	57	26 25
4	9.78999	16 16	9.89385	$\frac{26}{26}$	0.10615	9.89614	10 10	56	6 2.6 2.1 7 3.0 2.1
5	9.79015	16	9.89411	26	0.10589	9.89604 9.89594	10	55	1 81 351 33
6 7	9.79031 9.79047	16	9.89437 9.89463	26	0.10563 0.10537	9.89584	10	54 53	9 3.9 3.1
8	9.79063	16	9.89489	26	0.10511	9.89574	10	52	10 4.3 4.3 20 8.7 8.3
9	9.79079	16 16	9.89515	26 26	0.10485	9.89564	10 10	51	30 13 0 12 3
10	9.79095	16	9.89541	26	0.10459	9.89554	10	50	40 17.3 16.3
11 12	9.79111 9.79128	17	9.89567 9.89593	26	0.10433	9.89544 9.89534	10	49 48	50 21.7 20.5
13	9.79144	16	9.89619	26	0.10381	9.89524	10	47	l
14	9.79160	16 16	9.89645	26 26	0.10355	9.89514	10 10	46	17
15	9.79176	16	9.89671	26	0.10329	9.89504	9	45	6 1.7
16 17	9.79192 9.79208	16	9.89697 9.89723	26 26	0.10303	9.89495 9.89485	10	44 43	7 2.0 8 2.3
18	9.79224	16	9.89749	26	0.10251	9.89475	10	42	8 2.3 9 2.6
19	9.79240	16 16	9.89775	26 26	0.10225	9.89465	10 10	41	10 2.8
20	9.79256	16	9.89801	26	0.10199	9.89455	10	40	20 5.7
21 22	9.79272 9.79288	16	9.89827 9.89853	26 26	0.10173 0.10147	9.89445 9.89435	10	39 38	30 8.5 40 11.3
23	9.79304	16	9.89879	26	0.10121	9.89425	10	37	50 14.2
24	9.79319	15 16	9.89905	26 26	0.10095	9.89415	10 10	36	i .
25	9.79335	16	9.89931	26	0.10069	9.89405	10	35	
26 27	9.79351 9.79367	16	9.89957 9.89983	26 26	0.10043 0.10017	9.89395 9.89385	10	34	16 15 6 1.6 1.5
28	9.79383	16	9.90009	26	0.09991	9.89375	10	33 32	7 1.9 1.8
$\tilde{29}$	9.79399	16	9.90035	26	0.09965	9.89364	11	31	8 2.1 2.0
30	9.79415	16 16	9.90061	26 25	0.09939	9.89354	10 10	30	9 2.4 2.3 10 2.7 2.5
31 32	9.79431 9.79447	16	9.90086 9.90112	26	0.09914	9.89344 9.89334	10	29	20 5.3 5.0
33	9.79463	16	9.90138	26	0.09862	9.89324	10	28 27	30 8.0 7.5
34	9.79478	15	9.90164	$\frac{26}{26}$	0.09836	9.89314	10	26	40 10.7 10.0 50 13.3 12.5
35	9.79494	16 16	9.90190	26	0.09810	9.89304	10 10	25	00 10.0 12.0
36 37	9.79510 9.79526	16	9.90216	26 26	0.09784	9.89294	10	24 23	
38	9.79542	16	9.90242 9.90268	26	0.09733	9.89284 9.89274	10	22	11
39	9.79558	16	9.90294	26	0.09706	9.89264	10 10	21	6 1.1
40	9.79573	15	9.90320	26	0.09680	9.89254	10	20	7 1.3 8 1.5
41 42	9.79589 9.79605	16 16	9.90346	$\frac{26}{25}$	0.09654 0.09629	9.89244 9.89233	11	19	9 1.7
43	9.79621	16	9.90371 9.90397	26	0.09629	9.89233	10	18 17	10 1.8 20 3.7
44	9.79636	15	9.90423	26	0.09577	9.89213	10 10	16	30 5.5
45	9.79652	16 16	9.90449	26 26	0.09551	9.89203	10	15	40 7.3
46 47	9.79668 9.79684	16	9.90475	26 26	0.09525	9.89193 9.89183	10	14 13	50 9.2
48	9.79699	15	9.90501 9.90527	26	0.09499	9.89183	10	12	
49	9.79715	16	9.90553	26	0.09447	9.89162	11	iĩ	10 : 9
50	9.79731	16	9.90578	25	0.09422	9.89152	10	10	6 1.0 0.9
51	9.79746	15 16	9.90604	26 26	0.09396	9.89142	10 10	9	7 1.2 1.1
52 53	9.79762 9.79778	16	9.90630 9.90656	26	0.09370	9.89132 9.89122	10	8 7	8 1.3 1.2 9 1.5 1.4
54	9.79793	15	9.90682	26	0.09318	9.89112	10	6	10 1.7 1.5
55	9.79809	16	9.90708	26	0.09292	9.89101	11	5	20 3.3 3.0
56	9.79825	16 15	9.90734	$\frac{26}{25}$	0.09266	9.89091	10 10	4	30 5.0 4.5
57 58	9.79840 9.79856	16	9.90759 9.90785	26	0.09241 0.09215	9.89081 9.89071	10	3 2	40 6.7 6.0 50 8.3 7.5
59	9.79872	16	9.90811	26	0.09213	9.89060	11	ī	. 30 0.0 1.0
60	9.79887	15	9.90837	26	0.09163	9.89050	10	0	1
	L. Cos.	<u>d.</u>	L. Cotg.	d. e.	L.Tang.		d.	- -	P. P.

LOGARITHMS OF TRIGONOMETRIC FUNCTIONS.

_						39°				
	,	L. Sin.	d.	L.Tang.	d. c.	L. Cotg.	L. Cos.	d.	1	P. P.
-	0	9.79887	10	9.90837	00	0.09163	9.89050	10	60	
	1	9.79903	16 15	9.90863	26 26	0.09137	9.89040	10 10	59	
	2 3	9.79918 9.79934	16	9.90889 9.90914	25	0.09111	9.89030 9.89020	10	58 57	26
	4	9.79950	16	9.90940	26	0.09060	9.89009	īī	56	6 2.6
-	5	9.79965	15	9.90966	26	0.09034	9.88999	10	55	7 3.0
	6	9.79981	16	9.90992	26	0.09008	9.88989	10	54	8 3.5
	7	9.79996	15	9.91018	26	0.08982	9.88978	11	53	9 3.9 10 4.3
	8	9.80012	16	9.91043	25	0.08957	9.88968	10	52	20 8.7
1	9	9.80027	15	9.91069	26	0.08931	9.88958	10	51	30 13.0
ľ	10	9.80043	16	9.91095	26	0.08905	9.88948	10	50	40 17.3
ı	11	9.80058	15	9.91121	26	0.08879	9.88937	11	49	50 21.7
ı	12	9.80074	16 15	9.91147	26 25	0.08853	9.88927	10 10	48	
1	13	9.80089	16	9.91172	26	0.08828	9.88917	ii	47	
١	14	9.80105	15	9.91198	26	0.08802	9.88906	îô	46	25
١	15	9.80120	16	9.91224	26	0.08776	9.88896	10	45	6 2.5
١	16 17	9.80136	15	9.91250 9.91276	26	0.08750	9.88886	ii	44	7 2.9
1	18	9.80151 9.80166	15	9.91276	25	0.08724 0.08699	9.88875 9.88865	10	43 42	8 3.3 9 3.8
	19	9.80182	16	9.91327	26	0.08673	9.88855	10	41	10 4.2
			15		26			11		20 8.3
	20 21	9.80197 9.80213	16	9.91353 9.91379	26	0.08647 0.08621	9.88844 9.88834	10	40 39	30 12.5
1	22	9.80228	15	9.91404	25	0.08596	9.88824	10	38	40 16.7
- !	23	9.80244	16	9.91430	26	0.08570	9.88813	11	37	50 20.8
	24	9.80259	15	9.91456	26	0.08544	9.88803	10	36	
	25	9.80274	15	9.91482	26	0.08518	9.88798	10	35	
	26	9.80290	16	9.91507	25	0.08493	9.88782	11	34	16
	27	9.80305	15	9.91533	26	0.08467	9.88772	10	33	6 1.6
	28	9.80320	15	9.91559	26	0.08441	9.88761	11	32	7 1.9
	29	9.80336	16 15	9.91585	26 25	0.08415	9.88751	10 10	31	8 2.1
	30	9.80351	ı	9.91610		0.08390	9.88741		30	9 2.4 10 2.7
	31	9.80366	15 16	9.91636	26 26	0.08364	9.88730	11 10	29	20 5.3
	32	9.80382	15	9.91662	26	0.08338	9.88720	11	28	30 8.0
	33 34	9.80397 9.80412	15	9.91688 9.91713	25	0.08312	9.88709	10	27	40 10.7
			16		26	0.08287	9.88699	îĭ	26	50 13.3
	35 36	9.80428 9.80443	15	9.91739 9.91765	26	0.08261	9.88688	10	25	
	37	9.80458	15	9.91703	26	0.08235	9.88678 9.88668	ĩŏ	24 23	
	38	9.80473	15	9.91816	25	0.08209	9.88657	11	22	15
	39	9.80489	16	9.91842	26	0.08158	9.88647	10	21	6 1.5
	40	9.80504	15	9.91868	26	0.08132	9.88636	11	20	7 1.8
	41	9.80519	15	9.91893	25	0.08107	9.88626	10	19	8 2.0
	42	9.80534	15	9.91919	26	0.08081	9.88615	11	18	9 2.3 10 2.5
	43	9.80550	16	9.91945	26	0.08055	9.88605	10	17	20 5.0
	44	9.80565	15 15	9.91971	26 25	0.08029	9.88594	11 10	16	30 7.5
	45	9.80580		9.91996		0.08004	9.88584		15	40 10.0
	46	9.80595	15 15	9.92022	26 26	0.07978	9.88573	11 10	14	50 12.5
	47	9.80610	15	9.92048	26 25	0.07952	9.88563	11	13	
	48 49	9.80625 9.80641	16	9.92073 9.92099	26	0.07927	9.88552	10	12	
			15		26	0.07901	9.88542	îĭ	11	11 10
	50	9.80656	15	9.92125	25	0.07875	9.88531	10	10	6 1.1 1.0
	51 52	9.80671 9.80686	15	9.92150 9.92176	26	0.07850 0.07824	9.88521 9.88510	11	9	7 1.3 1.2
	53	9.80701	15	9.92202	26	0.07824	9.88499	11	7	8 1.5 1.3 9 1.7 1.5
	54		15	9.92227	25	0.07773	9.88489	10	6	10 1.8 1.7
	55	9.80731	15.	9.92253	26	0.07747	9.88478	11	5	20 3.7 3.3
	56		15	9.92279	26	0.07721	9.88468	10	4	30 5.5 5.0
	57		16	9.92304	25	0.07696	9.88457	11	3	40 7.3 6.7
	58	9.80777	15	9.92330	26	0.07670	9.88447	10	2	50 9.2 8.3
	59	9.80792	15 15	9.92356	26 25	0.07644	9.88436	11 11	1	
	60	9.80807	13	9.92381	20	0.07619	9.88425	11	0	
		L. Cos.	d.	L. Cotg.	d. c.	L.Tang.	L. Sin.	d.	-,-	P. P.

Column C						40°				
1 1 9.30822 15 9.92403 26 0.07568 9.88404 10 59 9.8867 15 9.92488 26 0.07564 9.88384 10 57 9.80862 15 9.92484 26 0.07542 9.88384 10 57 6 9.80872 15 9.92535 26 0.07542 9.88382 11 56 6 2.6 0.07489 9.88387 10 54 9.92535 26 0.07449 9.88362 11 55 8 3.5 9.92535 26 0.07449 9.88351 11 33 10 4.3 9.80927 15 9.92587 25 0.07389 9.88361 11 32 10 4.3 9.80927 15 9.92663 25 0.07382 9.88361 11 52 20 8.7 14 9.80977 15 9.92663 25 0.073281 9.88261 11 42 9.8 11 40 9.50 21.7 14 <t< th=""><th>′</th><th>L. Sin.</th><th>đ.</th><th>L.Tang.</th><th>d. c.</th><th></th><th></th><th>d.</th><th></th><th>P. P.</th></t<>	′	L. Sin.	đ.	L.Tang.	d. c.			d.		P. P.
1			15		26			10		
5 9.980852 15 9.92484 26 0.07516 9.88384 10 57 6 2.6 5 9.80887 15 9.92510 25 0.07465 9.88381 11 56 7 8.3.5 7 9.80912 15 9.92561 26 0.07489 9.88381 11 55 8 3.5 8 9.80927 15 9.92561 26 0.07489 9.88301 11 53 10 4.3 4.9 9.80927 15 9.92587 26 0.07382 9.88301 11 50 8.92681 15 9.92662 26 0.07382 9.88319 11 50 40 17.3 17.3 17.3 18.981017 15 9.92663 26 0.07381 9.88311 11 50 20 17.3 18.981017 15 9.92762 26 0.07228 9.88261 10 48 14 9.81017 16 9.81061 14 9.92314 <t< td=""><td></td><td></td><td>15</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></t<>			15							
4 9.00667 15 9.92464 25 0.07460 9.88361 11 55 8 3.5 7 9.80912 15 9.92551 25 0.07460 9.88362 10 54 9.89872 8 9.80927 15 9.92567 26 0.07463 9.88362 11 55 8 3.5 9 9.80942 15 9.92567 26 0.07439 9.88361 11 52 20 8.7 10 9.90957 15 9.92689 26 0.07363 9.88310 11 52 20 8.7 11 9.90972 15 9.92689 26 0.07363 9.88310 11 50 40 17.3 12 9.80987 15 9.92689 26 0.07337 9.88368 11 40 17.3 13 9.81002 15 9.92740 25 0.07280 9.88276 11 46 14 9.81017 15 9.92740 25 0.07280 9.88276 11 46 15 9.81032 15 9.92766 26 0.07234 9.88266 10 17 9.81061 15 9.92786 26 0.07284 9.88244 10 42 9 3.8 18 9.81076 15 9.92848 25 0.07383 9.88244 10 42 9 3.8 19 9.81091 15 9.92940 26 0.07182 9.88241 11 43 43 43 43 19 9.81091 15 9.92940 26 0.07080 9.88221 11 41 41 41 41 41 19 9.81091 15 9.92940 26 0.07080 9.88212 11 41 41 41 41 41 19 9.81091 15 9.92940 26 0.07085 9.88191 10 38 40 16.7 21 9.81166 15 9.92945 25 0.07085 9.88180 11 39 30 12.5 22 9.81136 15 9.93904 25 0.06967 9.88148 11 39 30 12.5 23 9.8124 14 9.93812 25 0.06967 9.88181 11 39 30 12.5 24 9.8125 15 9.93073 25 0.06967 9.88181 11 39 30 12.5 25 9.81340 15 9.93297 26 0.06660 9.88181 11 30 12.5 25 9.81341 15 9.93297 26 0.06660 9.88081 11 26 10 10 10 25 9.81341 15 9.93368 25 0.06667 9.88051 11 26 10 10 10 25 9.81360 15 9.93360 25 0.06660 9.88081 11 26 10 10 10 10 10 25 9.81361 14 9.93857 26 0.06660 9.88081 11 26 11 10 10 10 10 10 10 1	รี									
5 6 9.808697 15 9.92536 25 0.07480 9.88362 10 55 8 3.5 7 9.80912 15 9.92536 26 0.07489 9.88561 11 52 9.92587 26 0.07439 9.885851 11 52 20 8.4.3 3.5 9.92687 15 9.92683 26 0.07388 9.88390 11 52 20 8.7782 11 52 20 8.8359 11 50 40 17.0 4.3 11.0 9.92715 9.92683 26 0.07388 9.88391 11 40 15.0 9.92683 26 0.07381 9.88281 11 40 17.0 40 17.0 17.0 9.92716 26 0.07238 9.88281 11 47 42 29 26 0.07238 9.88255 11 44 42 29 25 0.07187 9.88224 10 42 29 11 44 7 2.29 11				9.92484		0.07516	9.88383			7 30
0 9 9.808912 15 9.92581 26 0.07483 9.88581 11 53 1 54 9 9 8.8992 11 52 20 8.7 3.9 9.8992 11 52 20 8.7 20 8.7 9.80927 15 9.92581 26 0.07483 9.88594 0 11 52 20 8.7 20 9.7 20 9.8 20 9.8 11 47 47 9.8 14 47 9.8 22 9.8 11 47 9.8 14 47 9.8 22 9.8 11 47 9.8 11 47 9.8 11 47 9.8 11 47 9.8 11 47 9.8 11 47 9.8										
8 9.80927 15 9.92587 26 0.07413 5.88340 11 52 10 4.3 9 9.80942 15 9.92638 26 0.07382 9.88300 11 50 30 13.0 13.0 13.0 13.0 13.0 13.0 13.0 40 17.3 30 13.0 13.0 13.0 40 71.7 30 13.0 40 71.7 30 13.0 13.0 13.0 13.0 13.0 40 17.3 30 13.0 13.0 13.0 40 40 71.7 30 13.0 13.0 40 40 71.3 40 21.7 40 40 71.3 40 22.5 11 47 47 40 40 71.3 41 49 50 21.7 9.80 11 47 47 40 40 40 42.5 40 41 49 50 21.7 41 40 42.5 40	6			9.92535						
Section Sect			15		26			11		
10							9.88330			
11	10									40 17.3
12 9.8007 15 9.92715 26 0.07285 9.88227 11 47 45 45 15 9.92716 25 0.07284 9.88266 10 45 6 2.5 2.5 17 9.81061 14 9.92817 25 0.07284 9.88266 10 45 6 2.5 17 9.81061 14 9.92817 25 0.07183 9.88244 10 45 7 2.9 17 9.81061 15 9.92843 25 0.07187 9.88224 11 44 47 2.9 9.8106 15 9.92843 25 0.07187 9.88224 11 41 42 9 3.8 19 9.81007 15 9.92892 26 0.07187 9.88224 11 42 9 3.8 19 9.8101 15 9.92894 26 0.07160 9.88212 11 40 20 8.3 21 9.81121 15 9.92924 26 0.07060 9.88212 11 40 20 8.3 40 16.7 22.9 9.81135 15 9.92945 25 0.07065 9.88101 11 37 37 30 12.5 39 30 12.5 39 30 12.5 39 30 12.5 39 30 12.5 39 30 30 30 30 30 30 30										50 21.7
14			15		26			11		
15										25
17 9.81061 14 9.92217 25 0.007183 9.8244 11 43 8 8.3 8.3 9.81076 15 9.92243 26 0.007187 9.88234 10 42 9 3.8 8.3 9.81076 15 9.92243 26 0.007182 9.88224 11 41 10 4.2 9 3.8 11 12 12 13 14 10 4.2 12 14 10 4.2 12 14 10 4.2 12 13 13 16 15 9.92240 26 0.007185 9.88212 11 41 10 4.2 20 8.3 30 12.5 12.5 13 13 30 12.5 13 13 16 15 9.92240 25 0.00705 9.88191 10 38 40 16.7 16 16 16 16 16 16 16 1	15	9.81032		9.92766		0.07234			45	6 2.5
18	16					0.07208				7 2.9
10										
20			15		25			11		
21 9.81121 15 9.92920 26 0.07080 9.88201 11 39 30 12.5										20 8.3
23	21			9.92920		0.07080	9.88201		39	
24 9.81166 15 9.92996 25 0.06978 9.88169 11 36 15 25 9.81180 15 9.93048 26 0.06978 9.88184 10 34 15 27 9.81210 15 9.93099 26 0.06991 9.88126 11 32 7 1.8 27 28 9.81240 15 9.93099 26 0.06901 9.88126 11 32 7 1.8 29 9.81240 15 9.93150 25 0.06826 9.88136 11 31 8 2.0 20 20 20 20 20 20 2				9.92945		0.07055	9.88191			
25					25					00 20.0
25			14		26			11		
27 9.81210 15 9.93073 25 0.06927 9.88137 11 33 32 7 1.8 29 9.81240 15 9.93124 25 0.06876 9.88115 11 31 32 7 1.8 29 9.81254 15 9.93150 25 0.06850 9.88105 11 31 32 7 1.8 31 9.81284 15 9.93217 25 0.06885 9.88094 11 29 10 2.5 32 9.81284 15 9.93227 26 0.06739 9.88083 11 29 10 2.5 33 9.81284 15 9.93227 26 0.06773 9.88072 11 27 30 7.5 34 9.81314 15 9.93227 25 0.06784 9.88061 11 26 40 10.0 35 9.81328 15 9.93232 25 0.06674 9.88061 11 26 40 10.0 36 9.81383 15 9.93330 25 0.06667 9.88040 11 24 37 9.81358 15 9.93330 26 0.06671 9.88029 11 23 38 9.81372 14 9.93354 25 0.06667 9.88018 11 22 40 9.81487 15 9.93480 26 0.06660 9.88018 11 22 41 9.81417 15 9.93431 25 0.06669 9.87985 11 12 42 9.81431 14 9.93457 26 0.06549 9.87996 11 20 8 1.9 43 9.81446 15 9.93482 25 0.06569 9.87985 11 19 9.3434 44 9.81461 15 9.93482 26 0.06549 9.87987 10 18 10 2.3 45 9.81475 14 9.93358 25 0.06569 9.87985 11 17 10 46 9.81475 14 9.93538 25 0.06617 9.87942 11 15 40 9.3 47 9.81501 14 9.93861 25 0.06339 9.87995 11 12 49 9.81534 15 9.93860 26 0.06339 9.87990 11 12 49 9.81534 15 9.93860 26 0.06339 9.87990 11 12 49 9.8159 14 9.93867 25 0.06287 9.87851 11 11 10 49 9.81560 15 9.93763 26 0.06339 9.87897 11 11 15 10 49 9.81560 15 9.93870 25 0.06684 9.87892 11 13 14 15 10 10 40 9.81697 15 9.93860 26 0.06313 9.87877 10 10 10 10 10 10 10										
29 9.81240 15 9.93124 25 0.06876 9.88115 11 31 31 8 2.0	27	9.81210								
30			15							
31 9.81289 15 9.93175 25 0.06825 9.88094 11 29 10 2.5 5.0 32 9.81284 15 9.93217 26 0.06799 9.88083 11 29 30 7.5 5.0 33 9.81299 15 9.93227 26 0.06773 9.88072 11 28 20 5.0 30 7.5 30 7.5 30 7.5 30 7.5 30 7.5 40 11 26 0.06799 9.88061 10 25 40 11 26 0.0673 9.88061 10 25 40 11 26 0.06792 9.88061 10 25 0.06697 9.88040 11 24 28 20 28 20 20 11 23 24 24 9.81372 14 9.8329 26 0.06697 9.88040 11 24 29.81497 29 9.93406 26 0.06699 9.87985 11										9 2.3
15										
33 9.81314 15 9.93252 25 0.06748 9.88061 11 26 50 10.0 12.5 35 9.81328 14 9.93278 26 0.06722 9.88061 11 26 50 12.5 36 9.81343 15 9.93303 25 0.06697 9.88061 11 25 37 9.81387 15 9.93329 26 0.06617 9.88029 11 23 39 9.81387 15 9.93380 26 0.06620 9.8807 11 22 14 40 9.81402 15 9.93490 26 0.06594 9.87986 11 22 14 41 9.81461 15 9.93482 25 0.06594 9.87975 10 18 10 2.3 44 9.81475 14 9.93508 25 0.06549 9.87942 11 17 20 4.7 45 9.81475 <td< td=""><td>32</td><td>9.81284</td><td></td><td>9.93201</td><td></td><td>0.06799</td><td>9.88083</td><td></td><td>28</td><td></td></td<>	32	9.81284		9.93201		0.06799	9.88083		28	
34 9.81328 14 9.93303 25 0.06697 9.88040 11 24 24 25 26 0.06662 9.88040 11 24 24 25 25 26 26 26 26 26 26										
36 9.81343 15 9.93303 25 0.06697 9.88040 11 24 37 9.81358 15 9.93329 26 0.06671 9.88029 11 23 39 9.81372 14 9.93354 25 0.06660 9.88018 11 22 6 1.4 40 9.81402 15 9.93496 26 0.06549 9.87996 11 21 7 1.6 41 9.81417 14 9.93457 26 0.06549 9.87996 11 12 7 1.6 8 1.9 44 9.81461 15 9.93457 25 0.06549 9.87955 10 18 10 2.2 45 9.81446 15 9.93482 25 0.06518 9.87964 11 17 20 4.7 46 9.81490 15 9.93559 26 0.06467 9.87931 11 16 30 7.0										
37 9.81358 15 9.938329 26 0.06671 9.88029 11 23 14 23 39 9.81387 15 9.93380 26 0.06640 9.88007 11 21 7 1.6 14 19.81417 15 9.93431 25 0.06620 9.89007 11 21 7 1.6 14 19.81417 15 9.93431 25 0.06659 9.87985 11 19 9 2.1 14 9.81446 15 9.93481 25 0.06569 9.87985 11 19 9 2.1 14 9.81446 15 9.93482 25 0.06549 9.87985 11 17 10 2.3 14 10.8146 15 9.93482 25 0.06549 9.87985 11 16 30 7.0 16 16 16 16 16 16 16 1			15							
38 9.81387 15 9.93380 26 0.06620 9.88007 11 21 7 1.6							9.88029		23	
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41 9.81417 15 9.93431 25 0.06569 9.87985 11 19 9 2.1 142 9.81431 14 9.93457 26 0.06543 9.87975 10 18 10 2.3 14 9.81466 15 9.93482 25 0.06518 9.87964 11 17 20 4.7 20 4.7 4.7 4.9.81461 15 9.93508 26 0.06492 9.87962 11 16 30 7.0 4.7 4.7 9.81476 14 9.93539 26 0.06441 9.87931 11 15 40 9.3 40 9.3 40 9.3 40 9.3 40 9.3 40 9.3 11 15 40 9.3 40 9.3 11 15 40 9.3 11 15 40 9.3 11 17 20 40 9.3 11 11 15 40 9.3 11 16 1.7										
14			15		25			11		
38 9.81446			14		26					
44 9.81461 14 9.93508 25 0.06492 9.87962 11 16 30 7.0 45 9.81470 15 9.93539 26 0.06467 9.87942 11 16 40 9.3 47 9.81509 15 9.93636 26 0.06416 9.87992 11 14 50 11.7 49 9.81519 14 9.93660 26 0.06339 9.87990 11 12 50 9.81563 15 9.93661 25 0.06339 9.87898 11 11 11 14 50 11.7 51 9.81569 15 9.93661 26 0.06339 9.87898 11 11 11 11 11 11 11 11 11 11 11 11 11 11 12 12 12 12 12 12 12 12 12 12 12 12 12 12 12	43	9.81446		9.93482						
15 9.81470 15 9.93533 26 0.06461 9.87931 11 14 50 11.7 46 9.81490 15 9.93539 26 0.06410 9.87931 11 14 50 11.7 47 9.81505 15 9.93536 26 0.06390 9.87990 11 13 49 9.81534 15 9.93636 26 0.06390 9.87990 11 12 49 9.81534 15 9.93636 25 0.06390 9.87990 11 12 49 9.81534 15 9.93636 26 0.06390 9.87890 11 11 10 50 9.81563 15 9.938712 25 0.06339 9.87887 11 10 51 9.81563 15 9.938712 25 0.06339 9.87887 11 10 52 9.81563 15 9.938712 25 0.06238 9.87857 11 8 8 1.5 1.3 53 9.81592 14 9.93878 26 0.06221 9.87855 11 7 9 1.7 1.5 54 9.81607 15 9.93778 26 0.06237 9.87844 11 6 10 1.8 1.7 55 9.81622 15 9.938710 25 0.06186 9.87822 11 4 30 5.5 5.0 56 9.81636 15 9.93841 26 0.06160 9.87821 11 3 40 7.3 6.7 58 9.81680 15 9.93840 25 0.06186 9.87821 11 3 40 7.3 6.7 59 9.81680 15 9.938916 26 0.06109 9.87789 11 1 1 6 0.06084 9.87788 11 11 10 70 70 70 70 70 70 70					25 25				-	30 7.0
1										
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$			15		25			11		50 11.7
10	48	9.81519		9.93610		0.06390	9.87909		12	
50 9.81549 10 9.93661 2 0.06339 9.87887 10 10 6 1.1 1.0 51 9.81563 14 9.93872 26 0.06313 9.87877 10 9 7 1.3 1.2 52 9.81578 15 9.93712 26 0.06282 9.87855 11 8 1.5 1.3 1.2 54 9.81607 15 9.93783 25 0.06287 9.87844 11 6 10 1.8 1.7 55 9.81622 15 9.93814 25 0.06227 9.87833 11 5 20 3.7 3.3 56 9.81651 15 9.93814 26 0.06160 9.87821 11 3 40 7.3 6.7 58 9.81680 15 9.93840 25 0.06160 9.87821 11 3 40 7.3 6.7 59 9.81694 14 <td< td=""><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>11 : 10</td></td<>										11 : 10
15										6 1.1 1.0
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$					25					
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$			14	9.93738	26				7	
55 9.81622 1 4 9.93789 0.06211 9.87832 11 5 20 3.7 3.5 5.6 56 9.81686 15 9.93814 25 0.06186 9.87822 11 4 30 5.5 5.0 58 9.81651 14 9.93865 25 0.06135 9.87800 11 1 3 40 7.3 6.7 59 9.81680 15 9.93891 26 0.06109 9.87789 11 1 1 1 60 9.81694 14 9.93916 25 0.06084 9.87778 11 0		9.81607		9.93763		0.06237				10 1.8 1.7
0.00169 0.001699 0.00169								1		
58 9.81665 14 9.93865 25 0.06135 9.87800 11 2 50 9.2 8.3 59 9.81680 15 9.93891 26 0.06135 9.87890 11 1 1 1 1 1 1 1 1 0 60 9.81694 14 9.93916 25 0.06084 9.87778 11 0 0										
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$			14		25			ii		
60 9.81694 9.93916 0.06084 9.87778 0										
L. Cos. d. L. Cotg. d. c. L. Tang. L. Sin. d. / P. P.	60	9.81694	14	9.93916	25	0.06084	9.87778	11	0	
	_	L. Cos.	d.	L. Cotg.	d.c.	L.Tang.	L. Sin.	d.	7	P. P.

_						4 1°				
	<u>′ </u>	L. Sin.	d.	L.Tang.	d. c.	L. Cotg.	L. Cos.	d.		P. P.
_	0	9.81694	15	9.93916	00	0.06084	9.87778	11	60	
	1	9.81709	15 14	9.93942	26 25	0.06058	9.87767	11 11	59	
	$\frac{\overline{2}}{3}$	9.81723 9.81738	15	9.93967 9.93993	26	0.06033	9.87756 9.87745	ii	58 57	26
	4	9.81752	14	9.93993	25	0.05982	9.87734	11	56	6 2.6
_	$\frac{3}{5}$	9.81767	15	9.94044	26	0.05956	9.87723	11	55	7 3.0
1	6	9.81781	14	9.94069	25	0.05931	9.87712	11	54 54	8 3.5
	7	9.81796	15	9.94095	26	0.05905	9.87701	11	53	9 3.9 10 4.3
1	8	9.81810	14	9.94120	25	0.05880	9.87690	11	52	20 8.7
١	9	9.81825	15 14	9.94146	26 25	0.05854	9.87679	11 11	51	30 13.0
I	10	9.81839		9.94171	ı	0.05829	9.87668		50	40 17.3
1	11	9.81854	15 14	9.94197	26 25	0.05803	9.87657	11 11	49	50 21.7
1	12	9.81868	14	9.94222	26	0.05778	9.87646	ii	48	
1	13 14	9.81882 9.81897	15	9.94248 9.94273	25	0.05752 0.05727	9.87635 9.87624	îî	47 46	
ŀ			14		26			11		25
ı	15 16	9.81911 9.81926	15	9.94299 9.94324	25	0.05701	9.87613 9.87601	12	45 44	6 \ 2.5 7 \ 2.9
1	17	9.81940	14	9.94350	26	0.05650	9.87590	11	43	8 3.3
ı	18	9.81955	15	9.94375	25	0.05625	9.87579	11	42	9 3.8
١	19	9.81969	14	9.94401	26	0.65599	9.87568	11	41	10 4.2
١	20	9.81983	14	9.94426	25	0.05574	9.87557	11	40	20 8.3
	21	9.81998	15	9.94452	26	0.05548	9.87546	11	39	30 12.5
i	22	9.82012	14 14	9.94477	25 26	0.05523	9.87535	11 11	38	40 16.7 50 20.8
	23 24	9.82026 9.82041	15	9.94503	25	0.05497	9.87524	ii	37 36	00 20.0
			14	9.94528	26	0.05472	9.87513	12		
	25	9.82055	14	9.94554	25	0.05446	9.87501	11	35 34	15
	26 27	9.82069 9.82084	15	9.94579 9.94604	25	0.05421	9.87490 9.87479	īī	33	6 1.5
	28	9.82098	14	9.94630	26	0.05370	9.87468	11	32	7 1.8
	29	9.82112	14	9.94655	25	0.05345	9.87457	11	31	8 2.0
	30	9.82126	14	9.94681	26	0.05319	9.87446	11	30	9 2.3
	31	9.82141	15	9.94706	25	0.05294	9.87434	12	29	10 2.5 20 5.0
	32	9.82155	14	9.94732	26 25	0.05268	9.87423	11 11	28	30 7.5
	33	9.82169	14 15	5.94757	26	0.05243	9.87412	11	27	40 10.0
	34	9.82184	14	9.34783	25	0.05217	9.87401	ii	26	50 12.5
	35	9.82198	14	9.94808	26	0.05192	9.87390	12	25	· ·
	36	9.82212 9.82226	14	9.94834 9.94859	25	0.05166	9.87378 9.87367	11	24 23	
	38	9.82240	14	9.94884	25	0.05116	9.87356	11	22	14
	39	9.82255	15	9.94910	26	0.05090	9.87345	11	21	6 1.4
	40	9.82269	14	9.94935	25	0.05065	9.87334	11	20	7 1.6 8 1.9
	41	9.82283	14	9.94961	26	0.05039	9.87322	12	19	9 2.1
	42	9.82297	14 14	9.94986	25 26	0.05014	9.87311	11 11	18	10 2.3
	43	9.82311	15	9.95012	25	0.04988	9.87300	12	17	20 4.7
	44	9.82326	14	9.95037	25	0.04963	9.87288	11	16	30 7.0
	45	9.82340	14	9.95062	26	0.04938	9.87277	11	15 14	40 9.3 50 11.7
	46 47	9.82354 9.82368	14	9.95088 9.95113	25	0.04912 0.04887	9.87266 9.87255	ii	13	50 11.7
	48		14	9.95139	'26	0.04861	9.87243	12	12	
	49		14	9.95164	25	0.04836	9.87232	11	11	12 11
	50	9.82410	14	9.95190	26	0.04810	9.87221	11	10	6 1.2 1.1
	51	9.82424	14	9.95215	25 25	0.04785	9.87209	12	9	7 1.4 1.3
	52	9.82439	15 14	9.95240	26	0.04760	9.87198	11 11	8	8 1.6 1.5
	58		14	9.95266	25	0.04734	9.87187	12	7	9 1.8 1.7
	54		14	9.95291	26	0.04709	9.87175	îĩ	6	10 2.0 1.8 20 4.0 3.7
	55		14	9.95317	25	0.04683	9.87164	11	5 4	30 6.0 5.5
	56 57		14	9.95342 9.95368	26	0.04658	9.87153 9.87141	12	3	40 8.0 7.3
	1 56		14	9.95398	25	0.04607	9.87130	11	2	50 10.0 9.2
	5		14	9.95418	25	0.04582	9.87119	11	ī	
	60	9.82551	14	9.95444	26	0.04556	9.87107	12	0	
		L. Cos.	d.	L. Cotg.	d. c.	L.Tang.	L. Sin.	d.	7	P. P.

					42°				
<u></u>	L. Sin.	đ.	L.Tang.	d. c.	L. Cotg.	L. Cos.	đ.	1	P. P.
0	9.82551	14	9.95444	25	0.04556	9.87107	11	60	
	9.82565	14	9.95469	26	0.04531	9.87096	11	59	
3	9.82579 9.82593	14	9.95495 9.95520	25	0.04505 0.04480	9.87085 9.87073	12	58 57	26
1 4	9.82607	14	9.95545	25	0.04455	9.87062	11	56	6 2.6 7 3.0
5	9.82621	14	9.95571	26	0.04429	9.87050	12	55	7 3.0 8 3.5
6	9.82635	14 14	9.95596	25 26	0.04404	9.87039	11	54	9 3.9
7	9.82649	14	9.95622	26 25	0.04378	9.87028	11 12	53	10 4.3
8	9.82663 9.82677	14	9.95647 9.95672	25	0.04353 0.04328	9.87016 9.87005	īī	52 51	20 8.7 30 13.0
10	9.82691	14	9.95698	26	0.04302	9.86993	12	50	40 17.3
lii	9.82705	14	9.95723	25	0.04277	9.86982	11	49	50 21.7
12	9.82719	14	9.95748	25	0.04252	9.86970	12	48	,
13	9.82733	14 14	9.95774	26 25	0.04226	9.86959	11 12	47	
14	9.82747	14	9.95799	26	0.04201	9.86947	11	46	25
15 16	9.82761 9.82775	14	9.95825 9.95850	25	0.04175 0.04150	9.86936 9.86924	12	45 44	6 2.5 7 2.9
17	9.82788	13	9.95875	25	0.04125	9.86913	11	43	8 3.3
18	9.82802	14	9.95901	26	0.04099	9.86902	11	42	9 3.8
19_	9.82816	14 14	9.95926	25 26	0.04074	9.86890	12 11	41	10 4.2
20	9.82830	14	9.95952	25	0.04048	9.86879	12	40	20 8.3 30 12.5
21 22	9.82844 9.82858	14	9.95977 9.96002	25	0.04023	9.86867 9.86855	12	39 38	40 16.7
23	9.82872	14	9.96028	26	0.03972	9.86844	11	37	50 20.8
24	9.82885	13	9.96053	25	0.03947	9.86832	12	36	
25	9.82899	14	9.96078	25	0.03922	9.86821	11	35	
26	9.82913	14 14	9.96104	26 25	0.03896	9.86809	12 11	34	14
27 28	9.82927	14	9.96129	26	0.03871	9.86798 9.86786	12	33	6 1.4 7 1.6
28	9.82941 9.82955	14	9.96155 9.96180	25	0.03845 0.03820	9.86775	11	32 31	8 1.9
30	9.82968	13	9.96205	25	0.03795	9.86763	12	30	9 2.1
31	9.82982	14	9.96231	26	0.03769	9.86752	11	29	10 2.3
32	9.82996	14 14	9.96256	25 25	0.03744	9.86740	12 12	28	20 4.7 30 7.0
33	9.83010	13	9.96281 9.96307	26	0.03719	9.86728 9.86717	11	27 26	40 9.3
	9.83023	14		25			12	25	50 11.7
35 36	9.83037 9.83051	14	9.96332 9.96357	25	0.03668 0.03643	9.86705 9.86694	11	25	
37	9.83065	14	9.96383	26	0.03617	9.86682	12	23	
38	9.83078	13 14	9.96408	25 25	0.03592	9.86670	12 11	22	6 1.3
39	9.83092	14	9.96433	26	0.03567	9.86659	12	21	7 1.5
40	9.83106	14	9.96459	25	0.03541	9.86647	12	20	8 1.7
41 42	9.83120 9.83133	13	9.96484 9.96510	26	0.03516 0.03490	9.86635 9.86624	īī	19 18	9 2.0
43	9.83147	14	9.96535	25	0.03465	9.86612	12	17	10 2.2 20 4.3
44	9.83161	14 13	9.96560	25 26	0.03440	9.86600	12 11	16	30 6.5
45	9.83174	14	9.96586	25	0.03414	9.86589	12	15	40 8.7
46	9.83188 9.83202	14	9.96611 9.96636	25	0.03389 0.03364	9.86577 9.86565	12	14 13	50 10.8
48	9.83202	13	9.96662	26	0.03338	9.86554	11	12	
49	9.83229	14	9.96687	25	0.03313	9.86542	12	iĩ	12 11
50	9.83242	13	9.96712	25	0.03288	9.86530	12	10	6 1.2 1.1
51	9.83256	14 14	9.96738	26 25	0.03262	9.86518	12 11	9	7 1.4 1.3
52 53	9.83270 9.83283	13	9.96763	25	0.03237	9.86507 9.86495	12	8	8 1.6 1.5
54	9.83297	14	9.96788 9.96814	26	0.03212 0.03186	9.86483	12	6	9 1.8 1.7 10 2.0 1.8
55	9.83310	13	9.96839	25	0.03161	9.86472	11	5	20 4.0 3.7
56	9.83324	14	9.96864	25	0.03136	9.86460	12	4	30 6.0 5.5
57	9.83338	14 13	9.96890	26 25	0.03110	9.86448	12 12	8	40 8.0 7.3
58 59	9.83351 9.83365	14	9.96915	25	0.03085	9.86436	11	2	50 10.0 9.2
		13	9.96940	26	0.03060	9.86425	12		
60	9.83378 L. Cos.	d.	9.96966 T. Cota	4 -	0.03034	9.86413	d.	0	P. P.
1	1 III. COS.	u.	L. Cotg.	d. c.	L.Tang.	L. Sin.	a.		

7	1	L. Sin.	d.	L.Tang.	d. c.	L. Cotg.	L. Cos.	d.		P. P.
0		9.83378	14	9.96966	25	0.03034	9.86413	12	60	
1	1	9.83392	13	9.96991	25	0.03009	9.86401	12	59	
2 3	1	9.83405 9.83419	14	9.97016 9.97042	26	0.02984 0.02958	9.86389 9.86377	12	58 57	26
4	1	9.83432	13	9.97067	25	0.02933	9.86366	11	56	6 2.6
- - 5	1 -	9.83446	14	9.97092	25	0.02908	9.86354	12	55	7 3.0
6		9.83459	13	9.97118	26	0.02882	9.86342	12	54	8 3.5 9 3.9
7		9.83473	14	9.97143	25	0.02857	9.86330	12	53	9 3.9 10 4.3
8		9.83486	13	9.97168	25	0.02832	9.86318	12	52	20 8.7
9		9.83500	14	9.97193	25	0.02807	9.86306	12	51	30 13.0
10	_	9.83513	13	9.97219	26	0.02781	9.86295	11	50	40 17.3
11		9.83527	14	9.97244	25	0.02756	9.86283	12	49	50 21.7
12		9.83540	13	9.97269	25 26	0.02731	9.86271	$\frac{12}{12}$	48	
13		9.83554	14 13	9.97295	25 25	0.02705	9.86259	12	47	
14		9.83567	14	9.97320	25	0.02680	9.86247	12	46	25
15		9.83581	13	9.97345	26	0.02655	9.86235	12	45	6 2.5
1 16		9.83594	14	9.97371	25	0.02629	9.86223	12	44	7 2.9
17		9.83608 9.83621	13	9.97396	$\widetilde{25}$	0.02604	9.86211 9.86200	iī	43	8 3.3
1 19		9.83634	13	9.97421 9.97447	26	0.02579 0.02553	9.86188	12	42 41	9 3.8 10 4.2
20	1-	9.83648	14	9.97472	25	0.02528	9.86176	12		20 8.3
2	:	9.83661	13	9.97472	25	0.02528	9.86164	12	40 39	30 12.5
1 2	5 I	9.83674	13	9.97523	26	0.02303	9.86152	12	38	40 16.7
1 2		9.83688	14	9.97548	25	0.02452	9.86140	12	37	50 20.8
$1\overline{2}$		9.83701	13	9.97573	25	0.02427	9.86128	12	36	
2	5	9.83715	14	9.97598	25	0.02402	9.86116	12	35	
1 2		9.83728	13	9.97624	26	0.02376	9.86104	12	34	14
\ 2	7	9.83741	13	9.97649	25	0.02351	9.86092	12	33	6 1.4
	8	9.83755	14 13	9.97674	25 26	0.02326	9.86080	12 12	32	7 1.6
1-	9	9.83768	13	9.97700	26 25	0.02300	9.86068	12	31	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
3		9.83781	14	9.97725	25	0.02275	9.86056	12	30	10 2.3
	1	9.83795	13	9.97750	25 26	0.02250	9.86044	12	29	20 4.7
	2	9.83808	13	9.97776	25	0.02224	9.86032	12	28	30 7.0
	1 K	9.83821 9.83834	13	9.97801 9.97826	$\widetilde{25}$	0.02199 0.02174	9.86020 9.86008	12	27 26	40 9.3
1-	<u></u>	9.83848	14	9.97851	25		9.85996	12	25	50 11.7
	36	9.83861	13	9.97877	26	0.02149 0.02123	9.85984	12	24	
	۶ ۶ ۱	9.83874	13	9.97902	25	0.02098	9.85972	12	23	
- 1:	38	9.83887	13	9.97927	25	0.02073	9.85960	12	22	13
- 13	39	9.83901	14	9.97953	26	0.02047	9.85948	12	21	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
4	10	9.83914	13	9.97978	25	0.02022	9.85936	12	20	$egin{array}{c c} 7 & 1.5 \\ 8 & 1.7 \\ \end{array}$
	41	9.83927	13	9.98003	25	0.01997	9.85924	12	19	9 2.0
	42	9.83940	13 14	9.98029	26 25	0.01971	9.85912	12 12	18	10 2.2
	43 44	9.83954	13	9.98054	25	0.01946	9.85900	12	17	20 4.3
- 1-		9.83967	13	9.98079	25	0.01921	9.85888	12	16	30 6.5
	45	9.83980	13	9.98104	26	0.01896	9.85876	12	15	40 8.7
	46 47	9.83993 9.84006	13	9.98130 9.98155	25	0.01870 0.01845	9.85864 9.85851	13	14 13	50 10.8
	48	9.84020	14	9.98180	25	0.01840	9.85839	12	12	
	49	9.84033	13	9.98206	26	0.01794	9.85827	12	11	
	50	9.84046	13	9.98231	25	0.01769	9.85815	12	10	
- 1	51	9.84059	13	9.98256	25	0.01744	9.85803	12	.9	7 1.4 1.3
- 1	52	9.84072	13	9.98281	25	0.01719	9.85791	12	8	8 1.6 1.5
- 1	53	9.84085	13 13	9.98307	26 25	0.01693	9.85779	12 13	7	9 1.8 1.7
	54	9.84098	14	9.98332	25 25	0.01668	9.85766	12	6	10 2.0 1.8
- 1	55	9.84112	13	9.98357	26	0.01643	9.85754	12	5	20 4.0 3.7
- 1	56	9.84125	13	9.98383	26 25	0.01617	9.85742	12	4	30 6.0 5.5 40 8.0 7.3
- 1	57	9.84138	13	9.98408	25	0.01592	9.85730	12	3 2	50 10.0 9.2
1	58 59	9.84151 9.84164	13	9.98433 9.98458	25	0.01567 0.01542	9.85718 9.85706	12	1	00 10.0 0.2
١	_		13		26	I		13		
	60	9.84177 L. Cos.	d.	9.98484 L. Cotg.	d. c.	0.01516	9.85693 L. Sin.	d.	,	P. P.
- 1	_	1 D. COS.	u.	L. Cotg.	u. c.	L.Tang.	1. 0111.	<u>u.</u>		1.1.

					44°				
′	L. Sin.	d.	L.Tang.	d. c.	L. Cotg.	L. Cos.	d.		P. P.
0	9.84177	13	9.98484	25	0.01516	9.85693	12	60	1
$\frac{1}{2}$	9.84190 9.84203	13	9.98509 9.98534	25	0.01491 0.01466	9.85681 9.85669	12	59 58	
3 l	9.84216	13	9.98560	26	0.01440	9.85657	12	57	6 2.6
4	9.84229	13 13	9.98585	25 25	0.01415	9.85645	12 13	56	6 2.6 7 3.0
5	9.84242		9.98610	25	0.01390	9.85632	12	55	8 3.5
6	9.84255	13 14	9.98635	26	0.01365	9.85620	12	54	9 3.9
7 8	9.84269 9.84282	13	9.98661 9.98686	25	0.01339 0.01314	9.85608 9.85596	12	53 52	10 4.3 20 8.7
9	9.84295	13	9.98711	25	0.01289	9.85583	13	51	30 13.0
10	9.84308	13	9.98737	26	0.01263	9.85571	12	50	40 17.3
11	9.84321	13 13	9.98762	25 25	0.01238	9.85559	12 12	49	50 21.7
12	9.84334	13	9.98787	25 25	0.01213	9.85547	13	48	
13 14	9.84347 9.84360	13	9.98812 9.98838	26	0.01188 0.01162	9.85534 9.85522	12	47 46	
15	9.84373	13	9.98863	25	0.01137	9.85510	12	45	6 2.5
16	9.84385	12	9.98888	25	0.01112	9.85497	13	44	7 2.9
17	9.84398	13 13	9.98913	25 26	0.01087	9.85485	12 12	43	8 3.3
18 19	9.84411 9.84424	13	9.98939 9.98964	20 25	0.01061	9.85473	13	42 41	9 3.8
20	9.84424	13	9.98989	25	0.01036	9.85460	12	40	20 8.3
21	9.84450	13	9.999015	26	0.01011	9.85436	12	39	30 12.5
22	9.84463	13	9.99040	25	0.00960	9.85423	13	38	40 16.7
23	9.84476	13 13	9.99065	25 25	0.00935	9.85411	12 12	37	50 20.8
24	9.84489	13	9.99090	26	0.00910	9.85399	13	36	
25 26	9.84502 9.84515	13	9.99116 9.99141	25	0.00884 0.00859	9.85386 9.85374	12	35 34	14
27	9.84528	13	9.99166	25	0.00834	9.85361	13	33	6 1.4
28	9.84540	12	9.99191	25	0.00809	9.85349	12 12	32	7 1.6
29	9.84553	13 13	9.99217	26 25	0.00783	9.85337	13	31	8 1.9 9 2.1
30	9.84566	13	9.99242	25	0.00758	9.85324	12	30 29	10 2.3
$\frac{31}{32}$	9.84579 9.84592	13	9.99267 9.99293	26	0.00733	9.85312 9.85299	13	28	20 4.7
33	9.84605	13	9.99318	25	0.00682	9.85287	12 13	27	30 7.0 40 9.3
34	9.84618	13 12	9.99343	25 25	0.00657	9.85274	12	26	50 11.7
35	9.84630	13	9.99368	26	0.00632	9.85262	12	25	l '
36 37	9.84643 9.84656	13	9.99394 9.99419	25	0.00606 0.00581	9.85250 9.85237	13	24 23	
38	9.84669	13	9.99444	25	0.00556	9.85225	12	22	13
39	9.84682	13	9.99469	25 26	0.00531	9.85212	13 12	21	6 1.3 7 1.5
40	9.84694	12 13	9.99495	26 25	0.00505	9.85200	13	20	8 1.7
41	9.84707	13	9.99520	25 25	0.00480	9.85187 9.85175	12	19 18	9 2.0
42 43	9.84720 9.84733	13	9.99545 9.99570	25	0.00430	9.85162	13	17	10 2.2 20 4.3
44	9.84745	12	9.99596	26	0.00404	9.85150	12 13	16	30 6.5
45	9.84758	13	9.99621	25	0.00379	9.85137	12	15	40 8.7
46	9.84771	13 13	9.99646	25 26	0.00354	9.85125	13	14	50 10.8
47 48	9.84784 9.84796	12	9.99672 9.99697	25	0.00328 0.00303	9.85112 9.85100	12	13 12	
49	9.84809	13	9.99722	25	0.00278	9.85087	13	ii	
50	9.84822	13	9.99747	25	0.00253	9.85074	13	10	6 1.2
51	9.84835	13	9.99773	26 25	0.00227	9.85062	12 13	9	7 1.4
52	9.84847	12 13	9.99798	25 25	0.00202	9.85049	12	8 7	8 1.6
53 54	9.84860 9.84873	13	9.99823 9.99848	25	0.00177 0.00152	9.85037 9.85024	13	6	9 1.8 10 2.0
55	9.84885	12	9.99874	26	0.00132	9.85012	12	5	20 4.0
56	9.84888	13	9.99874	25	0.00126	9.84999	13	4	30 6.0
57	9.84911	13	9.99924	25	0.00076	9.84986	13	8	40 8.0
58	9.84923	12 13	9.99949	25 26	0.00051	9.84974	12 13	2	50 10.0
59	9.84936	13	9.99975	26 25	0.00025	9.84961	12	1	
60	9.84949		0.00000		0.00000	9.84949		0	
	L. Cos.	d.	L. Cotg.	d. c.	L.Tang.	L. Sin.	d.	<u> </u>	P. P.

TRAVERSE TABLES.

To use the tables, find the number of degrees in the left-hand column if the angle be less than 45°, and in the right-hand column if greater than 45°, The numbers on the same line running across the page are the latitudes and \mathbf{d} epartures for that angle and for the respective distances, 1, 2, 3, 4, 5, 6, 7, 8, 9, \mathbf{w} hich appear at the top and bottom of the pages. Thus, if the bearing of a line be 10° and the distance 4, the latitude will be 3.939 and the departure O.695; with the same bearing, and the distance 8, the latitude will be 7.878 and the departure 1.389. The latitude and departure for 80 is 10 times the latitude and departure for 8, and is found by moving the decimal point one place to the right; that for 500 is 100 times the latitude and departure for 5, and is found by moving the decimal point two places to the right and so on. By moving the decimal point one, two, or more places to the right, the latitude and departure may be found for any multiple of any number given in the table. In finding the latitude and departure for any number such as 458, the number is resolved into three numbers, viz.: 400, 50, 3, and the latitude and departure for each taken from the table and then added together.

We thus obtain the following:

Rule.—Write down the latitude and departure, neglecting the decimal points, for the first figure of the given distance; write under them the latitude and departure for the second figure, setting them one place farther to the right; under these, place the latitude and departure for the third figure, setting them one place still farther to the right, and so continue until all the figures of the given distance have been used, and these latitudes and departures and latitude on the right. been used; add these latitudes and departures, and point off on the right of their sums a number of decimal places equal to the number of decimal places to which the tables being used are carried; the resulting numbers will be the latitude and departure of the given distance in feet links, chains, or whatever unit of measurement is adopted.

EXAMPLE.—A bearing is 16° and the distance 725 ft.: what is the latitude

and departure?

Distances.	Latitudes.	Departures.
700	6729	1929
20	1923	0551
5	4806	1 3 7 8
725	6 9 6.9 3 6	199.788

Taking the nearest whole numbers and rejecting the decimals, we find the latitude and departure to be 697 and 200.

When a 0 occurs in the given number, the next figure must be set two

places to the right as in the following example:
The bearing is 22° and the distance 907 ft; required, the latitude and departure.

Distances. 9 0 0	Latitudes. 8345	Departures. 3371
	man or	
7	6490	2622
907	8 4 0.9 9 0	$3\ 3\ 9.7\ 2\ 2$
		and in the las

Here the place of 0 both in the distance column and in the latitude and departure columns is occupied by a dash—. Rejecting the decimals, the latitude is 841 ft. and the departure 340 ft. When the bearing is more than 45°, the names of the columns must be read from the bottom of the page. The latitude of any bearing, as 60° , is the departure of its complement, 30° ; and the departure of any bearing, as 30° , is the latitude of its complement, 60° . Where the bearings are given in smaller fractions of degrees than is found in the table, the latitudes and departures can be found by interpolation.

										, ,
Bearing.				2		3		4	5	er age
Bes	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	1
0°	1.000	0.000	2.000 2.000	0.000	3.000	0.000	4.000 4.000	0.000 0.017	5.000	891 891
0 1	1.000 1.000 1.000	0.004 0.009	2.000 2.000 2.000	0.017	3.000 3.000 3.000	0.026 0.039	4.000 4.000	0.035	5.000 5.000	801
10 10	1.000 1.000	0.013 0.017	2.000 2.000	0.026 0.035	3.000	0.039	4.000 3.999	0.052 0.070	5.000 4.999	89°
11	1.000 1.000	0.022	2.000	0.044	2.999	0.065	3.999	0.087	4.999	881
11	1.000 1.000	0.026 0.031	1.999 1.999	0.052 0.061	2.999 2.999	0.079	3.999 3.998	0.105 0.122	4.998 4.998	881
1 1 20	0.999	0.035	1.999	0.070	2.998	0.105	3.998	0.140	4.997	881 88°
91	0.999	0.035 0.039	1.998	0.070	2.998	0.118 0.131	3.997	0.157 0.174 0.192	4.996	87± 87±
21 21 30	0.999 0.999	0.044 0.048	1.998 1.998	0.087 0.096	2.997 2.997	0.131	3.996 3.995	0.174	4.995 4.994	871
30	0.999	0.052	1.997	0.105	2.996	0.144 0.157	3.995	0.209	4.993	87 <u>1</u> 87°
3½ 3½	0.998 0.998	0.057 0.061	1.997 1.996	0.113 0.122	2.995 2.994	0.170 0.183	3.994	0.227 0.244	4.992 4.991	86‡ 86‡
3 1 40	0.998	0.065 0.070	1.996	0.122 0.131 0.140	2.994	0.196	3.991	0.262	4.989	861
40 41	0.998 0.997	0.070 0.074	1.995 1.995	0.140 0.148	2.993 2.992	0.209 0.222	3.990 3.989	0.279 0.296	4.988 4.986	86° 85‡
41	0.997	ი.078	1.994	0.146	2.991	0.235	3.988	0.314	4.985	851
41	0.997	0.083	1.993	0.166	2.990	0.248	3.986	0.331	4.983	851
5º	0.996	0.087 0.092	1.992 1.992	0.174	2.989 2.987	0.261	3.985 3.983	0.349	4.981 4.979	85° 84‡
51 51	0.996 0.995	0.096	1.991	0.183 0.192	2.986	0.275 0.288	3.982	0.366 0.383	4.977	84
5 1 60	0.995	0.100	1.990	0.200	2.985	0.301	3.980	0.401 0.418	4.975	841 84°
61 1	0.995 0.994	0.105 0.109	1.989 1.988	0.209 0.218	2.984 2.982	0.314 0.327	3.978 3.976	0.435	4.973 4.970	831
61 61 70	0.994	0.113	1.987	0.226	2.981	0.340	3.974	0.453	4.968	834
6 1	0.993 0.993	$0.118 \\ 0.122$	1.986 1.985	0.235 0.244	2.979 2.978	0.353 0.366	3.972 3.970	0.470 0.487	4.965 4.963	83 ¹ / ₂
71 71	0.992	0.196	1.984	0.252	0.076	0.379	3.968	0.505	4 960	821
7±	0.991 0.991	0.131	1.983 1.982	0.261	2.974 2.973	0.392 0.405	3.966 3.963	0.522	4.957	821
7 1 80	0.990	0.131 0.135 0.139	1.981	0.252 0.261 0.270 0.278 0.287	2.971	0.418	3.961	0.539 0.557	4.957 4.954 4.951	82± 82± 82± 82°
8 1 81	0.990 0.989	0.143	1.979	$0.287 \\ 0.296$	2.969 2.967	0.430 0.443	3.959 3.956	0.574 0.591	4.948 4.945	1 814
8 1	0.988	0.148 0.152	1.978 1.977	0.304	2.965	0.456	3.953	0.608	4.942	811 811 810
8 1 90	0.988	0.156	1.975	0.313	2.963	0.469	3.951 3.948	0.626 0.643	4.938 4.935	81° 80 1
9 <u>‡</u>	0.987 0.986	0.161 0.165	$1.974 \\ 1.973$	0.321 0.330	2.961 2.959	0.482 0.495	3.945	0.660	4.931	801
9‡	0.986	0.169	1.971	0.339	2.957	0.508	3.942	0.677	4.928	80 1
10°	0.985	0.174	1.970	0.347 0.356	2.954	0.521 0.534	3.939 3.936	0.695	4.924 4.920	80° 79‡
101 101	0.984 0.983	$0.178 \\ 0.182$	1.968 1.967	0.364	2.952 2.950	0.547	3.933	0.712 0.729	4.916	791
10	0.982	0.187	1.965	0.373	2.947	0.560	3.930	0.746	4.912	79 1 7 9 0
110 111	0.982 0.981	0.191 0.195	1.963 1.962	0.382 0.390	2.945 2.942	0.572 0.585	3.927 3.923	0.763 0.780	4.908 4.904	781
11#	0.980	0.199	1.960	0.399	2.940	0.598	3.920	0.797	/ 1 Onn	781
11 1 120	0.979 0.978	0.204 0.208	1.958 1.956	0.407 0.416	$2.937 \\ 2.934$	0.611 0.624	3.916 3.913	0.815 0.832	4.895 4.891	78 1 78°
121	0.977	0.212	1.954	0.424	2.932	0.637	3.909	0.849	4.886	77∄
121	0.976 0.975	$0.216 \\ 0.221$	1.953 1.951	$0.433 \\ 0.441$	2.929 2.926	0.649	3.905 3.901	0.866 0.883	4.881 4.877	771 771 710
12# 3 0	0.974	0.225	1.949	0.450	2.923	0.662 0.675	3.897	0.900	4.872	770
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
Bearing.		1		2	:	3		8	5	Bearing.

	5		8		7	1	В	,	9	<u>i</u>
Bear	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Bearing.
0 1 0 1 00	0.000	6.000	0.000	7.000	0.000	8.000	0.000	9.000	0.000	90°
0 1	0.022	6.000	0.026 0.052	7.000 7.000	0.031	8.000	0.035 0.070	9.000	0.039	89#
01	0.044 0.065	6.000 5.999	0.052	6.999	0.061 0.092	8.000 7.999		9.000 8.999	0.079 0.118	89 1 89 1
Ŏį	0.087	5.999 5.999	0 105	6.999 6.998	0.122 0.153	7.999 7.998	0.140 0.175 0.209 0.244 0.279	8.999	0.157	89°
11 11 11 20	0.109	5.999 5.998	0.131	6.998	0.153	7.998	0.175	8.998	0.196	88#
11	0.131 0.153	5.997	0.157 0.183	6.998 6.997	0.183	7.997 7.996	0.209	8.997 8.996	0.236 0.275	881 881
20	0.174	5.996	0.209	6.996	0.214 0.244 0.275 0.305 0.336	7.995	0.279	8.995	0.314	880
21	0.196	5.995	0.209 0.236	6.996 6.995	0.275	7.994	0.314	8.993	0.353	87 1
21	0.218	5.994	0.262	6.993 6.992	0.305	7.992 7.991	0.349 0.384	8.991 8.990	0.393 0.432	871
2; 2; 2; 3; 3; 3;	0.240 0.262 0.283	5.993 5.992	0.262 0.288 0.314	6.990	0.366	7.989	0.419	8.988	0.471	87 1 87°
31	0.283	5.990	0.340	6.989	0.366 0.397	7.987	0.454	8.986	0.510	86#
31	0.305 0.327 0.349	5.989 5.987	0.366 0.392	6.987 6.985	0.427 0.458	7.985 7.983	0.488	8.983 8.981	0.549	86± 86±
31	0.349	5.985	0.392	6.983	0.488	7.981	0.558	8 078	0.589 0.628	860
41	0.371	5.984	0.445	6.981 6.978	0.519	7.981 7.978	0.384 0.419 0.454 0.488 0.523 0.558 0.593 0.628	8.975	0.667	85#
44	0.392 0.414	5.982 5.979	0.471 0.497	6.978 6.976	0.549	7.975	0.628 0.662	8.972 8.969	0.706	851
60	0.414	5.977	0.523	6.973	0.580	7.973	0.697	8.966	0.745	85 ¹ 85°
51 51 51 60	0.458	5.975	0.549	6.971	0.641	7.966	0.037	8 069	0.784	847
5	0.479	5.972 5.970	0.575	6.968	0.671	7.963	0.767	8.959	0.863	84
5	0.501	5.970 5.967	0.601	6.971 6.968 6.965 6.962	0.701	7.960	0.732 0.767 0.802 0.836	8.955	0.902 0.941	84 ¹ 84°
61	0.523 0.544	5.964	0.653	6.958	0.762	7.956 7.952	0.830	8.951 8.947	0.941	83 1
61 61 61 7°	0.566 0.588	5.961 5.958	0.653 0.679	6.958 6.955	0.771 0.701 0.732 0.762 0.792 0.823	7.952 7.949	0.871 0.906 0.940 0.975 1.010	8.942	1.019	83 i
1 67	0.588	5.958	0.705	6.951	0.823	7.945	0.940	8.938	1.058	831
71	0.609	5.955 5.952	0.731 0.757	6.948	U.803	7.940 7.936	1.010	8.933 8.928	1.097 1.136	83° 82‡
7	0.631 0.653 0.674	5.949 5.945	0.783	6.944 6.940	0.883 0.914	7.932	1.044	8.923	1.175	82 1
71 71 71 80 81 81 81 81 81	0.674	5.945	0.783 0.809 0.835	6.936 6.932	0.944 0.974	7.927 7.922	1.044 1.079 1.113 1.148	8.918 8.912	1.214 1.253	82½ 82°
81	0.090	5.942 5.938	0.835	6.932	1 004	7.922	1.113	8.912	1.253	81 1
8	0.696 0.717 0.739	1 5.934	0.861 0.887	6.928 6.923	1.004 1.035	7.912	1.182	8.901	1.291 1.330 1.369	81 1
83	0.761 0.782	5.930	0.913	6.919	1.065 1.095	7.907	1.182 1.217	8.901 8.895	1.369	81 <u>‡</u> 81°
97	0.782	5.926 5.922	0.939 0.964	6.914 6.909	1.095	7.902 7.896	1.251 1.286 1.320	8.889 8.883	1.408 1.447	80 1
9 <u>1</u>	0.804 0.825	5.918	0.990	6.904	1.125 1.155	7.890	1.320	8.877	1.485	801
9₽	0.847	5.913	1.016	6.899	1.185	7.884	1.355	8.870	1.524	80 ¹ / ₄
10°	0.868	5.909	1.042	6.894	1.216	7.878	1.389	8.863	1.563	80°
10 1 10 1	0.890 0.911	5.904 5.900	1.068	6.888 6.883	1.246 1.276	7.872 7.866	1.424	8.856 8.849	1.601 1.640	79 1 791
104	0.933	5.895	1.093 1.119	6.877	1.306	7.860	1.492	8.842	1 679	791
10 1 	0.933 0.954 0.975	5.895 5.890	1.145	6.871	1.336	7.853	1.526	8.835	1.717	79°
11 1 11 1	0.975	5.885 5.880	1.171 1.196	6.866	1.306 1.336 1.366 1.396 1.425	7.846	1.458 1.492 1.526 1.561 1.595 1.629 1.663 1.697 1.732	8.827 8.819	1.717 1.756 1.794	78≩ 78≩
111	1.018	5.874	1.222	6.853	1.425	7.839 7.832	1.629	8.811	1.833	78 <u>‡</u>
11 1 12°	1.040	5.869	1.247	6.859 6.853 6.847	1.400	7.825	1.663	8.803	1.871	78°
121	1.061 1.082	5.863 5.858	1.273 1.299	6.841 6.834	1.485 1.515	7.818	1.697	8.795	1.910	77#
121 121	1.103	5.852	1.324	6.827	1.545	7.810 7.803	1.766	8.787 8.778	1.948 1.986	77 k
130	1.125	5.846	1.350	6.821	1.545 1.575	7.803 7.795	1.800	8.778 8.769	2.025	77 1 77°
Beering.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Bearing.
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Bearing.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	1
130	0.974	0.225	1.949	0.450	2.923	0.675	3.897	0.900	4.872	77
13 1 13 1	0.973 0.972	0.229 0.233	1.947 1.945	0.458 0.467	2.920 2.917	0.688 0.700	3.894 3.889	0.917 0.934	4.867 4.862	76 76
13 1	0.971	0.238	1.943	0.475	2.914	0.713	3.885	0.951	4.857	76
140 141	0.970 0.969	0.242	1.941 1.938	0.484 0.492	2.911 2.908	0.726 0.738 0.751	3.881 3.877	0.968 0.985	4.851 4.846	76 75
141	0.968	0.246 0.250	1.936	0.501	2.904	0.751	3.873	1.002	4.841	75
14#	0.967	0.255	1.934	0.509	2.901	0.764	3.868	1.018	4.835	75
15° 15‡	0.966 0.965	0.259 0.263	1.932 1.930	0.518 0.526	2.898 2.894	0.776 0.789	3.864 3.859	1.035 1.052	4.830 4.824	75°
15	0.964	0.267	1.927	0.534	2.891	0.802	3.855	1.069	4.818	74
15 1 16°	0.962	0.271	1.925	0.543	2.887 2.884	0.814 0.827	3.850	1.086 1.103	4.812 4.806	74 ¹ 74 ⁰
16 1	0.961 0.960	0.276 0.280	1.923 1.920	0.551 0.560	2.880	0.839	3.845 3.840	1.119	4.800	73}
16	0.959	0.284	1.918	0.568	2.876	0.852	3.835	1.136	4.794	731
16‡	0.958 0.956	0.288 0.292	1.915 1.913	0.568 0.576 0.585	2.873 2.869	0.865 0.877	3.830 3.825	1.153 1.169	4.788 4.782	73 ¹ 73°
170 17‡	0.955	0.297	1.910	0.593	2.865	0.890	3.820	1.186	4.775	721
17	0.954	0.301	1.907	0.601	2.861	0.902	3.815	1.203	4.769	72
17∄ 18°	0.952 0.951	0.305 0.309	1.905 1.902	0.610 0.618	2.857 2.853	0.915 0.927	3.810 3.804	1.220 1.236	4.762 4.755	72 1 72°
181	0.950	0.313	1.899	0.626	2.849	0.939	3.799	1.258	4.748	71#
18 1 18 1	0.948 0.947	0.317 0.321	1.897 1.894	0.635 0.643	2.845 2.841	0.952 0.964	3.793 3.788	1.269 1.286	4.742	71± 71±
195	0.946	0.326	1.891	0.651	2.837	0.977	3.782	1.302	4.735 4.728 4.720	710
194	0.944	0.330	1.888	0.659	2.832	0.989	3.776	1.319	4.720	70 1
19 1 19 1	0.943 0.941	0.334 0.338	1.885 1.882	0.668 0.676	2.828 2.824	1.001 1.014	8.771 8.765	1.335 1.352	4.713 4.706	701 701
20°	0.940	0.342	1.879	0.684	2.819	1.026	3.759	1.368	4.698	70°
201	0.938	0.346	1.876	0.692	2.815	1.038	3.753	1.384	4.691	691
201 201	0.937 0.935	0.350 0.354	1.873 1.870	0.700 0.709	2.810 2.805	1.051 1.063	3.747 3.741	1.401 1.417	4.683 4.676	691
210	0.934	0.358	1.867	0.717	2.801	1.075	3.734	1.433	4.668	69°
211 211	0.932	0.362	1.864	0.725	2.796	1.087	3.728	1.450	4.660 4.652	683
21#	0.930 0.929	0.367 0.371	1.861 1.858	0.725 0.733 0.741	2.791 2.786	1.100 1.112	3.722 3.715	1.466 1.482	4.632	68 1 68 1
220	0.927	0.375	1.854	0.749	2.782	1.124	3.709	1.498	4.636	680
22 1 22 1	0.926 0.924	0.379 0.383	1.851 1.848	0.757 0.765	$2.777 \\ 2.772$	1.136 1.148	3.702 3.696	1.515 1.531	4.628 4.619	67∄ 67å
224	0.924	0.387	1.844	0.773	2.767	1.140	3.689	1.547	4.611	67±
23°	0.921	0.391	1.841	0.781	2.762	1.172	3.682	1.563	4.603	67. 67°
$\frac{231}{231}$	0.919 0.917	0.395 0.399	1.838 1.834	0.789 0.797	2.756 2.751	1.184 1.196	8.675 3.668	1.579 1.595	4.594 4.585	661
23₹	0.915	0.403	1.831	0.805	2.746	1.208	3.661	1.611	4.577	66 1 661
24°	0.914	0.407	1.827	0.813	2.741	1.220	3.654	1.627	4.568	66°
$24\frac{1}{4}$ $24\frac{1}{6}$	0.912 0.910	0.411 0.415	1.824 1.820	0.821 0.829	2.735 2.730	1.232 1.244	3.647 3.640	1.648 1.659	4.559 4.550	65‡ 65‡
243	0.908	0.419	1.816	0.837	2.724	1.256	3.633	1.675	4.541	65 <u>i</u>
250	0.906	0.423	1.813	0.845	2.719	1.268	3.625	1.690	4.532	65°
25‡ 25‡	0.904	0.427 0.431	1.809 1.805	0.853 0.861	2.713 2.708	1.280 1.292	3.618 3.610	1.706 1.722	4.522 4.513	64 1 641
25₹	0.901	0.434	1.801	0.869	2.702	1.303	3.603	1.738	4.503	641
26°	0.899	0.438	1.798	0.877	2.696	1.315	3.595	1.753	4.494	64°
Bearing.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Bearing.
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9		Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Bearing.
1 1 1 1 1	30 31 31 31 40 41	1.125 1.146 1.167 1.188 1.210 1.231 1.252	5.846 5.840 5.834 5.828 5.822 5.815 5.809	1.350 1.375 1.401 1.426 1.452 1.477 1.502 1.528	6.821 6.814 6.807 6.799 6.792 6.785 6.777	1.575 1.604 1.634 1.664 1.693 1.723 1.753	7.795 7.787 7.779 7.771 7.762 7.754 7.745	1.800 1.834 1.868 1.902 1.935 1.969 2.003	8.769 8.760 8.751 8.742 8.733 8.723 8.713	2.025 2.063 2.101 2.139 2.177 2.215 2.253	77° 761 761 761 762 751 751
	44 50 15½ 15½ 16½ 16½ 17½ 17½ 17½ 18½ 18½ 190	1.278 1.294 1.315 1.357 1.378 1.399 1.420 1.441 1.462 1.483 1.504 1.524 1.566 1.566 1.567 1.607	5.802 5.796 5.789 5.775 5.768 5.760 5.745 5.738 5.730 5.725 5.714 5.706 5.698 5.690 5.682 5.673	1.528 1.553 1.573 1.603 1.629 1.654 1.704 1.729 1.754 1.779 1.804 1.829 1.854 1.879 1.902 1.953	6.769 6.761 6.754 6.737 6.729 6.720 6.703 6.694 6.685 6.667 6.657 6.648 6.639 6.619	1.782 1.812 1.841 1.900 1.929 1.959 1.988 2.017 2.047 2.076 2.105 2.134 2.163 2.192 2.221 2.250 2.279	7.736 7.727 7.718 7.700 7.690 7.680 7.671 7.661 7.650 7.640 7.630 7.698 7.598 7.598 7.598	2.037 2.071 2.104 2.138 2.172 2.205 2.239 2.272 2.306 2.339 2.372 2.409 2.472 2.505 2.505 2.572 2.605	8.703 8.693 8.683 8.662 8.651 8.640 8.629 8.618 8.607 8.595 8.595 8.572 8.560 8.547 8.535 8.522 8.510	2.291 2.329 2.367 2.405 2.443 2.518 2.594 2.631 2.669 2.744 2.781 2.818 2.856 2.893 2.930	754 744 744 744 734 734 734 724 724 714 714 716
	19 1 19 1 19 1	1.648 1.669 1.690	5.665 5.656 5.647	1.978 2.003 2.028	6.609 6.598 6.588	2.308 2.337 2.365	7.553 7.541 7.529	2.638 2.670 2.703	8.497 8.484 8.471	2.967 3.004 3.041	70∄ 70⅓ 70⅓
	20°- 204 207 207 207 207 207 207 207 207 207 207	1.710 1.731 1.751 1.771 1.792 1.812 1.833 1.853 1.873 1.394 1.954 1.954 2.014 2.034 2.034 2.073 2.173 2.133 2.153 2.173	5.638 5.620 5.611 5.691 5.592 5.582 5.563 5.563 5.533 5.523 5.502 5.492 5.492 5.471 5.490 5.449 5.427 5.438	2.052 2.072 2.101 2.126 2.175 2.199 2.223 2.248 2.272 2.320 2.344 2.392 2.416 2.464 2.464 2.464 2.512 2.536 2.559 2.589 2.589	6.578 6.567 6.557 6.546 6.524 6.513 6.502 6.490 6.479 6.467 6.455 6.444 6.432 6.370 6.382 6.370 6.381 6.305	2.394 2.4251 2.480 2.597 2.537 2.566 2.594 2.622 2.651 2.679 2.707 2.785 2.763 2.791 2.819 2.847 2.875 2.903 2.903 2.958 3.944 3.944 3.944	7.518 7.508 7.493 7.493 7.456 7.456 7.443 7.410 7.417 7.404 7.391 7.364 7.336 7.336 7.322 7.308 7.294 7.250 7.255 7.250 7.250 7.250 7.250	2.736 2.769 2.802 2.834 2.900 2.932 2.967 3.029 3.029 3.061 3.126 3.126 3.150 3.254 3.254 3.318 3.318 3.318 3.318 3.413 3.413	8.457 8.4430 8.416 8.402 8.388 8.374 8.354 8.330 8.285 8.206 8.254 8.238 8.225 8.206 8.173 8.157 8.140 8.123 8.103	3.078 3.1152 3.189 3.2262 3.299 3.3371 3.408 3.444 3.553 3.589 3.625 3.696 3.732 3.804 3.804 3.839 3.871	70° 69± 69± 68± 68± 68± 67± 67± 66± 66± 65± 65± 64± 64± 64±
	26°	2.192	5.393	2.630 Lat.	6.292	3.069	7.190	3.507	8.089	3.945	64‡ 64°
	Bearing.	Lat.	Dep.	8	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Bearing.

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Bearing.			2		3			4	5	11
8	Lat.	Dep.	Lat.	Dep.	Lat.	Дер.	Lat.	Dep.	Lat	
26°	0.899	0.438	1.798	0.877	2.696	1.315	3.595	1.753	4.494	, a
261	0.897	0.442 0.446	1.794 1.790	0.885 0.892	2.691 2.685	1.327 1.339	3.587	1.769 1.785	4.484	
261 261	0.895 0.893	0.440	1.786	0.892	2.689	1.339	3.580 3.572	1.785	4.475 4.465	68
27°	0.891	0.454	1.782	0.908	2.673	1.350 1.362	2 564	1.816	4.455	63
271	0.889	0.458	1.778	0.916	2.667	1.374	3.556	1.831	4.445	62
271 271	0.887 0.885	0.462 0.466	1.774 1.770	0.923 0.931	2.661 2.655	1.385	3.548 3.540	1.847 1.862	4.435 4.425	62 62
280	0.883	0.469	1.766	0.939	2.649	1.408	3.532	1.878	4.415	62
28 1	0.881	0.473	1.762	0.947	2.643	1.420	3.524	1.893	4.404	61
28i 28i	0.879 0.877	0.477 0.481	1.758 1.753	0.954 0.962	2.636 2.630	1.431 1.443	3.515 3.507	1.909 1.924	4.394 4.384	61
290	0.875	0.485	1.749	0.970	2.624	1.454	3.498	1.939	4.384	61 61
29 1	0.872	0.489	1.745 1.741	0.977	2.617	1.466	3.490	1.954	4.362	601
291	0.870 0.868	0.492 0.496	1.741 1.736	0.985 0.992	2.611	1.477	3.481	1.970	4.352	601
29‡ 30°	0.866	0.500	1.732	1.000	2.605	1.489	3.473	1.985	4.341	60
301 301	0.864	0.504	1.728	1.000	2.598	1.500 1.511	3.454	2.000	4.330 4.319	60° 59‡
30 1	0.862	0.508	1.723	1.015	2.585	1.523	3.447	2.030	4.308	594
301	0.859 0.857	0.511	1.719	1.023	2.578	1.534	3.438	2.045	4.308 4.297	501
31 ⁰	0.855	0.515 0.519	1.714 1.710	1.030 1.038	2.572 2.565	1.545 1.556	3.429 3.420	2.060 2.075	4.286 4.275	59°
31½ 31¼	0.853	0.500	1.705 1.701	1.045 1.052	2.558	1.567 1.579	3.411	2.090	4.263	584
31∄ 32°	0.850	0.526 0.530 0.534 0.537	1.701	1.052	2.551	1.579	3.401	2.105	4.252	58 <u>‡</u>
32±	0.848 0.846	0.530	1.696 1.691	1.060 1.067	2.544 2.537	1.590 1.601	3.392 3.383	2.120 2.134	4.240	580
321	0.843	0.537	1.687	1.075	2.530	1.612	3.374	2.134	4.229 4.217	57∄ 57▮
32	0.841	0.54i	1.682	1.082	2.523	1.623	3.364	2.164	4.205	571 57°
33° 33‡	0.839 0.836	0.545 0.548	1.677 1.673	1.089 1.097	2.516 2.509	1.634 1.645	3.355 3.345	2.179 2.193	4.193	57°
331	0.834	0.552	1.668	1.104	2.502	1.656	3.336	2.193	4.181 4.169	561 561
33 1	0.831	0.556	1.663	1.111	2.494	1.667	3.326	2.222	4.157	56 <u>₹</u>
34°	0.829 0.827	0.559 0.563	1.658 1.653	1.118 1.126	2.487 2.480	1.678 1.688	3.316 3.306	2.237 2.251	4.145	56°
341	0.824	0.566	1.648	1.133	2.472	1.699	3.297	2.266	4.133 4.121	55 1 551
34	0.822	0.570	1.643	1.140	2.465	1.710	3.287	2.280	4.108	551
35°	0.819	0.574	1.638	1.147	2.457	1.721	3.277	2.294	4.096	55°
351	0.817	0.577	1.633	1.154	2.450	1.731	3.267	2.309	4.083	544
35‡ 35‡	0.814 0.812	0.581 0.584	1.628 1.623	1.161 1.168	2.442 2.435	1.742 1.753	3.257 3.246	2.323 2.337	4.071 4.058	541 541
36°	0.809	0.588	1.618	1.176	2.427	1.763 1.774	3.236	2.351	4.045	540
36 1	0.806	0.591	1.613	1.183	2.419	1.774	3.226	2.365	4.032	534
36⅓ 36⅔	0.804 0.801	0.595 0.598	1.608 1.603	1.190 1.197	2.412 2.404	1.784 1.795	3.215 3.205	2.379 2.393	4.019 4.006	531
37°	0.799	0.602	1.597	1.204	2.396	1.805	3.195	2.407	3.993	53 1 53°
37‡	0.796	0.605	1.592	1.211	2 388	1.816	3.184	2.421	3.980	52 1
371 371	0.793 0.791	0.609 0.612	1.587 1.581	1.218 1.224	$\frac{2.380}{2.372}$	1.826 1.837	3.173 3.163	2.435 2.449	3.967 3.953	52
38°	0.788	0.616	1.576	1.231	2.364	1.847	3.152	2.463	3.940	52 ¹ 52°
381	0.785	0.619	1.571	1.238	2.356	1.857	3.141	2.476	3.927	51#
38‡ 38‡	0.783 0.780	0.623 0.626	1.565 1.560	1.245 1.252	2.348 2.340	1.868 1.878	3.130 3.120	2.490	3.913	511
390	0.777	0.629	1.554	1.259	2.331	1.888	3.120	2.504 2.517	3.899 3.886	51 ¹ 51 ⁰
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Bearing.	1		1	?		 }		4	5	Boaring.

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	Бер.	Dav.	Dep.	1.6.0.	Dep.	Lat.	Бер.			
26°	2.192	5.393 5.381	2.630 2.654	6.292 6.278	3.069 3.096	7.190 7.175	3.507 3.538	8.089 8.072	3.945 3.981	64° 63‡
261 261	2.211 2.231	5.370	2.677	6.265	3.123	7.160	3.570	8.054	4.016	634
26‡ 27°	2.250 2.270	5.358 5.346	2.701 2.724	6.251 6.237	3.151 3.178	7.144 7.128	3.601 3.632	8.037 8.019	4.051 4.086	63 ¹ 63°
27‡	2.289	5.334 5.322	2.747	6.223	3.205	7.112	3.663	8.001	4.121	62∄
271	2.309 2.328	5.322 5.310	2.770 2.794	6.209 6.195	3.232 3.259	7.096 7.080	3.694 3.725	7.983 7.965	4.156 4.190	621 621
280	2.347	5.298	2.817	6.181	3.286	7.064	3.756	7.947	4.225	62°
281 281	2.367 2.386	5.285 5.273	2.840 2.863	6.166 6.152	3.313 3.340	7.047 7.031	3.787 3.817	7.928 7.909	4.260 4.294	61# 61#
281	2.405	5.260	2.886	6.137	3.367	7.014	3.848	7.891	4.329	61 ±
29°	2.424 2.443	5.248 5.235	2.909 2.932	6.122 6.107	3.394 3.420	6.997 6.980	3.878 3.909	7.872 7.852	4.363 4.398	60 1
291	2.462	5.222	2.955	6.093	3.447	6.963	3.939	7.833	4.432	60i
29‡	2.481	5.209	2.977	6.077	3.474	6.946	3.970	7.814	4.466	601
30 1	2.500 2.519	5.196 5.183	3.000 3.023	6.062 6.047	3.500 3.526	6.928 6.911	4.000 4.030	7.794 7.775	4.500 4.534	60° 59≩
301	2.538	5.170	3.045	6.031	3.553	6.893	4.060	7.755	4.568	591
30 1	2.556 2.575	5.156 5.143	3.068 3.090	6.016 6.000	3.579 3.605	6.875 6.857	4.090 4.120	7.735 7.715	4.602 4.635	59‡ 59 °
311	2.594	5.129	3.113	5.984	3.631	6.839	4.150	7.694	4.669	58#
31‡ 31‡	2.612 2.631	5.116 5.102	3.135 3.157	5.968 5.952	3.657 3.683	6.821 6.803	4.180 4.210	7.674 7.653	4.702 4.736	58∤ 58∤
32°	2.650	5.088	3.180	5.936	3.709	6.784	4.239	7.632	4.769	58°
324	2.668 2.686	5.074 5.060	$\frac{3.202}{3.224}$	5.920 5.904	3.735 3.761	6.766 6.747	4.269 4.298	7.612 7.591	4.802 4.836	57≹ 57≹
321 321	2.705	5.046	3.246	5.887	3.787	6.728	4.298	7.569	4.869	571 571
33°	2.723	5.032 5.018	3.268 3.290	5.871	3.812 3.838	6.709	4.357	7.548	4.902 4.935	57° 56 1
33‡	2.741 2.760	5.003	3.312	5.854 5.837	3.864	6.690 6.671	4.386 4.416	7.527 7.505	4.967	561
33₽	2.778	4.989	3.333	5.820	3.889	6.652	4.445	7.483	5.000	56 1
34° 34‡	2.796 2.814	4.974 4.960	3.355 3.377	5.803 5.786	3.914 3.940	6.632 6.613	4.474 4.502	7.461 7.439	5.033 5.065	56° 55‡
341 341	2.832 2.850	4.945 4.930	3.398 3.420	5.786 5.769 5.752	3.965 3.990	6.593 6.573	4.531 4.560	7.417 7.395	5.098 5.130	551 551
350	2.868	4.915	3.441	5.734	4.015	6.553	4.589	7.372	5.162	550
351	2.886	4.900 4.885	3.463	5.716	4.040	6.533	4.617	7.350	5.194	54₹
351 351	2.904 2.921	4.869	3.484 3.505	5.699 5.681	4.065 4.090	6.513 6.493	4.646 4.674	7.327 7.304	5.226 5.258	541 541
360	2.939	4.854	3.527	5.663	4.115	6.472	4.702	7.281	5.290	54°
361 361	2.957 2.974	4.839 4.823	3.548 3.569	5.645 5.627	4.139 4.164	6.452 6.431	4.730 4.759	7.258 7.235	5.322 5.353	53‡ 53‡
364	2.992	4.808	3.590	5.609	4.188	6.410	4.759 4.787	7.211	5.385	$53\frac{1}{4}$
37° 37‡	3.009 3.026	4.792 4.776	3.611 3.632	5.590 5.572	4.213 4.237	6.389 6.368	4.815 4.842	7.188 7.164	5.416 5.448	53° 52‡
371	3.044	4.760	3.653	5.554	4.261	6.347	4.870	7.140	5.479	$52\frac{1}{2}$
37 1 38°	3.061 3.078	4.744 4.728	3.673 3.694	5.535 5.516	4.286 4.310	6.326 6.304	4.898 4.925	7.116 7.092	5.510 5.541	52‡ 52°
38‡	3.095	4.712	3.715	5.497	4.334	6.283	4.953	7.068	5.572	51#
381	3.113 3.130	4.696 4.679	3.735 3.756	5.478 5.459	4.358 4.381	6.261 6.239	4.980 5.007	7.043 7.019	5.603 5.633	511 511
390	3.147	4.663	3.776	5.440	4.405	6.217	5.035	6.994	5.664	510
je L	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
Bearing.	5		B	:	7		3	8)	Bearing.

Bearing.		1		2		3		4	5	-
898	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
39½	0.777 0.774	0.629 0.633	1.554 1.549	1.259 1.265	2.331 2.323	1.888 1.898	3.109 3.098	2.517 2.531	3.886 3.872	51°
39	0.772	0.636	1.543	1.272	2.315	1.908	8.086	2.544	3.858	504
39‡		0.639	1.538	1.279	2.307	1.918	3.075	2.558	3.844	501
40° 40‡	0.766 0.763	0.643 0.646	1.532 1.526	1.286 1.292	2.298 2.290	1.928 1.938	3.064 3.053	2.571 2.584	3.830 3.816	56° 49 1
40 i	0.760	0.649	1.521	1.299	2.281	1.948 1.958	3.042	2.598 2.611	3.802 3.788	491 491
40 } 41°	0.758 0.755	0.653 0.656	1.515 1.509	1.306 1.312	2.273 2.264	1.968	3.030 3.019	2.624	3.774 3.759	490
41 41 	0.752 0.749	0.659 0.663	1.504 1.498	1.319 1.325	2.256 2.247	1.978 1.988	3.007 2.996	2.637 2.650	3.759 3.745	48 1 481
41₹	0.746	0.666	1.492	1.332 1.338	2.238	1.998	2.984	2.664	3.730	481
420	0.743 0.740	0.669 0.672	1.486 1.480	1.338 1.345	2.229 2.221	2.007 2.017	2.973 2.961	2.677 2.689	3.716 3.701	48°
42 1 421	0.737 0.734	0.676	1.475	1.351 1.358	2.212	2.027	2.949	2.702 2.715	3.686	471
42 1	0.734 0.731	0.679 0.682	1.469 1.463	1.358 1.364	2.203 2.194	2.036 2.046	2.937 2.925	2.715 2.728	3.672 3.657	47½ 47°
43‡	0.728	0.685	1.457	1.370	2.185	2.056	2.913	2.741	3.642	461
431 431	0.725 0.722	0.688 0.692	1.451 1.445	1.377 1.383	2.176 2.167	2.065 2.075	2.901 2.889	2.753 2.766	3.627 3.612	461 461
440	0.719	0.695	1.439	1.389	2.158	2.084	2.877	2.779	3.597	460
44‡ 44‡	0.716 0.713	0.698 0.701	1.433 1.427	1.396 1.402	2.149 2.140	2.093 2.103	2.865 2.853	2.791 2.804	3.582 3.566	454 454
441	0.710	0.704	1.420	1.408	2.131	2.112	2.841	2.816	3.551	451
45°	0.707	0.707	1.414	1.414	2.121	2.121	2.828	2.828	3.536	45°
Bear- ing.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Bear- ing.
ring.	5		8		,		3			ring
Bearing.	bep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Bearing.
39°	Dep.	Lat.	Dep.	Lat. 5.440	Dep.	Lat.	Dep.	Lat. 6.994	Dep.	510
	Dep.	Lat.	Dep. 3.776 3.796 3.816	Lat. 5.440 5.421 5.401	Dep.	Lat. 6.217 6.195 6.173	Dep. 5.035 5.062 5.089	Lat. 6.994 6.970 6.945	Dep. 5.664 5.694 5.725	\$1° 50 1 50 <u>1</u>
39° 39‡ 39‡	Dep. 3.147 3.164 3.180 3.197	Lat. 4.663 4.646 4.630 4.613	Dep. 3.776 3.796 3.816 3.837	Lat. 5.440 5.421 5.401 5.382	Dep. 4.405 4.429 4.453 4.476	Lat. 6.217 6.195 6.173 6.151	Dep. 5.035 5.062 5.089 5.116	Lat. 6.994 6.970 6.945 6.920	Dep. 5.664 5.694 5.725 5.755	502 502 504 504
39° 39‡ 39‡ 40°	Dep. 3.147 3.164 3.180 3.197	Lat. 4.663 4.646 4.630 4.613 4.596	Dep. 3.776 3.796 3.816 3.837 3.857	Lat. 5.440 5.421 5.401 5.382 5.362	Dep. 4.405 4.429 4.453 4.476 4.500	Lat. 6.217 6.195 6.173 6.151 6.128	Dep. 5.035 5.062 5.089 5.116 5.142	Lat. 6.994 6.970 6.945 6.920 6.894	Dep. 5.664 5.694 5.725 5.755 5.785	501 501 501 501 500
39° 39¼ 39¼ 39¾ 40° 40¼ 40¼	Dep. 3.147 3.164 3.180 3.197 3.214 3.231 3.247	Lat. 4.663 4.646 4.630 4.613 4.596 4.579 4.562	Dep. 3.776 3.796 3.816 3.837 3.857 3.877 3.897	Lat. 5.440 5.421 5.401 5.382 5.362 5.343 5.323	Dep. 4.405 4.429 4.453 4.476 4.500 4.523 4.546	Lat. 6.217 6.195 6.173 6.151 6.128 6.106 6.083	5.035 5.062 5.089 5.116 5.142 5.169 5.196	6.994 6.970 6.945 6.920 6.894 6.869 6.844	5.664 5.694 5.725 5.755 5.785 5.815 5.845	51° 50‡ 50‡ 50‡ 50° 49‡ 49‡
39° 39¹ 39¹ 39³ 40° 40¹ 40¹ 40³ 40°	Dep. 3.147 3.164 3.180 3.197 3.214 3.231 3.247 3.264 3.280	Lat. 4.663 4.646 4.630 4.613 4.596 4.579 4.562 4.545	Dep. 3.776 3.796 3.816 3.837 3.857 3.877 3.897 3.917	5.440 5.421 5.401 5.382 5.362 5.343 5.323 5.303 5.283	Dep. 4.405 4.429 4.453 4.476 4.500 4.523 4.546 4.569	6.217 6.195 6.173 6.151 6.128 6.106 6.083 6.061	Dep. 5.035 5.062 5.089 5.116 5.142 5.169 5.196 5.222 5.248	6.994 6.970 6.945 6.920 6.894 6.869 6.844 6.818 6.792	Dep. 5.664 5.694 5.725 5.755 5.815 5.845 5.875 5.905	50° 50° 50° 50° 49° 49° 49° 49°
39° 39¹ 39¹ 39³ 40° 40¹ 40¹ 40³ 40°	Dep. 3.147 3.164 3.180 3.197 3.214 3.231 3.247 3.264 3.280 3.297	Lat. 4.663 4.646 4.630 4.613 4.596 4.579 4.562 4.545 4.528 4.511	Dep. 3.776 3.796 3.816 3.837 3.857 3.877 3.897 3.936 3.936 3.956	Lat. 5.440 5.421 5.401 5.382 5.362 5.343 5.323 5.303 5.263	Dep. 4.405 4.429 4.453 4.476 4.500 4.523 4.546 4.569 4.592 4.615	6.217 6.195 6.173 6.151 6.128 6.106 6.083 6.061 6.038 6.015	Dep. 5.035 5.062 5.089 5.116 5.142 5.169 5.196 5.222 5.248 5.275	6.994 6.970 6.945 6.920 6.894 6.869 6.844 6.818 6.792 6.767	5.664 5.694 5.726 5.755 5.785 5.815 5.845 5.845 5.906 5.934	50° 50° 50° 50° 49° 49° 49° 48° 48°
39° 39° 39° 39° 40° 40° 40° 40° 41° 41° 41° 41° 41°	Dep. 3.147 3.164 3.180 3.197 3.214 3.231 3.247 3.264 3.280 3.297 3.313 3.329	Lat. 4.663 4.6463 4.630 4.613 4.579 4.562 4.545 4.528 4.518 4.494 4.476	Dep. 3.776 3.796 3.816 3.837 3.857 3.897 3.917 3.936 3.956 3.976 3.995	Lat. 5.440 5.421 5.401 5.382 5.362 5.343 5.323 5.303 5.283 5.243 5.222	Dep. 4.405 4.425 4.453 4.476 4.500 4.523 4.546 4.569 4.592 4.615 4.638	Lat. 6.217 6.195 6.173 6.151 6.128 6.106 6.083 6.061 6.038 6.015 5.992	Dep. 5.035 5.069 5.116 5.142 5.169 5.196 5.222 5.248 5.275 5.301 5.327	6.994 6.970 6.945 6.920 6.894 6.869 6.844 6.818 6.792 6.741 6.715	Dep. 5.664 5.725 5.725 5.785 5.815 5.845 5.875 5.905 5.904 5.993	50° 50° 50° 49° 49° 49° 48° 48° 48° 48° 48°
39° 39¹ 39¹ 39² 40° 40¹ 40¹ 41¹ 41² 41² 41²	Dep. 3.147 3.164 3.180 3.197 3.214 3.231 3.243 3.290 3.297 3.313 3.329 3.3329 3.346	Lat. 4.663 4.646 4.630 4.613 4.596 4.579 4.562 4.545 4.528 4.511 4.494 4.476 4.459	Dep. 3.776 3.796 3.816 3.837 3.857 3.897 3.917 3.936 3.956 3.956 3.995 4.015	Lat. 5.440 5.421 5.401 5.382 5.362 5.343 5.323 5.263 5.263 5.263 5.222 5.202	Dep. 4.405 4.429 4.453 4.476 4.500 4.523 4.5469 4.592 4.615 4.661 4.684	Lat. 6.217 6.195 6.173 6.151 6.128 6.106 6.083 6.061 6.038 6.015 5.995 5.945	Dep. 5.035 5.062 5.089 5.116 5.142 5.169 5.122 5.248 5.275 5.301 5.327 5.353	Lat. 6.994 6.970 6.945 6.920 6.894 6.869 6.848 6.792 6.767 6.767 6.715 6.688	Dep. 5.664 5.694 5.725 5.785 5.815 5.875 5.875 5.905 5.934 5.993 6.022	50° 50° 50° 50° 49° 49° 49° 48° 48° 48° 48° 48°
39° 394 394 40° 404 404 414 414 414 412 424	Dep. 3.147 3.164 3.180 3.197 3.214 3.234 3.264 3.280 3.297 3.313 3.329 3.346 3.362 3.378	Lat. 4.663 4.646 4.630 4.613 4.596 4.5762 4.545 4.528 4.514 4.494 4.476 4.459 4.441 4.424	Dep. 3.776 3.796 3.816 3.837 3.857 3.897 3.917 3.936 3.956 3.995 4.015 4.034	Lat. 5.440 5.421 5.401 5.382 5.362 5.363 5.283 5.283 5.223 5.222 5.202 5.161	Dep. 4.405 4.429 4.453 4.476 4.500 4.523 4.546 4.569 4.592 4.615 4.638 4.661 4.634 4.707 4.729	Lat. 6.217 6.195 6.173 6.151 6.128 6.106 6.083 6.061 6.038 6.015 5.992 5.968 5.942 5.988	Dep. 5.035 5.062 5.089 5.116 5.142 5.169 5.222 5.285 5.275 5.301 5.327 5.353 5.379 5.405	Lat. 6.994 6.970 6.945 6.920 6.894 6.864 6.818 6.792 6.741 6.715 6.688 6.662 6.635	Dep. 5.664 5.694 5.725 5.785 5.815 5.875 5.905 5.904 5.993 6.021 6.080	50° 50° 50° 50° 49° 49° 48° 48° 48° 48° 47° 47° 47° 47°
39° 394 394 40° 404 404 414 414 414 42° 424 424	Dep. 3.147 3.164 3.180 3.197 3.214 3.231 3.247 3.264 3.280 3.297 3.313 3.346 3.362 3.378 3.394	Lat. 4.663 4.646 4.630 4.613 4.579 4.562 4.5428 4.511 4.494 4.476 4.459 4.441 4.424 4.406	Dep. 3.776 3.796 3.816 3.837 3.857 3.897 3.996 3.956 3.956 3.995 4.015 4.034 4.073	Lat. 5.440 5.421 5.382 5.362 5.362 5.343 5.323 5.283 5.263 5.263 5.263 5.262 5.161 5.140	Dep. 4.405 4.429 4.453 4.476 4.500 4.523 4.546 4.566 4.638 4.661 4.684 4.707 4.729 4.752	Lat. 6.217 6.195 6.173 6.151 6.128 6.106 6.083 6.061 6.038 6.015 5.992 5.998 5.945 5.922 5.875	Dep. 5.035 5.062 5.089 5.1169 5.142 5.169 5.222 5.248 5.275 5.301 5.353 5.379 5.430	Lat. 6.994 6.970 6.945 6.920 6.894 6.864 6.818 6.792 6.741 6.715 6.682 6.662 6.635 6.689	Dep. 5.664 5.694 5.725 5.785 5.815 5.845 5.895 5.905 5.934 5.963 6.022 6.051 6.080	503 504 504 504 504 494 494 488 488 488 488 478 478 478
391 391 391 391 401 401 401 411 411 411 421 421 421 421 421 421 42	Dep. 3.147 3.164 3.180 3.197 3.214 3.231 3.243 3.264 3.280 3.297 3.346 3.362 3.378 3.378 3.394 3.416	Lat. 4.663 4.646 4.633 4.596 4.579 4.5645 4.528 4.511 4.476 4.476 4.441 4.424 4.406 4.388 4.370	Dep. 3.776 3.796 3.816 3.837 3.857 3.897 3.917 3.936 3.956 3.956 4.015 4.034 4.073 4.073 4.073 4.073	Lat. 5.440 5.421 5.362 5.362 5.343 5.363 5.283 5.263 5.263 5.263 5.261 5.140 5.110 5.199	Dep. 4.405 4.429 4.453 4.476 4.500 4.523 4.5469 4.569 4.615 4.681 4.681 4.707 4.729 4.752 4.772 4.772	Lat. 6.217 6.195 6.175 6.195 6.106 6.106 6.088 6.061 6.038 6.015 5.995 5.968 5.945 5.945 5.875 5.857	Dep. 5.035 5.062 5.082 5.169 5.116 5.142 5.169 5.222 5.248 5.275 5.353 5.377 5.353 5.370 5.430 5.4430 5.4481	Lat. 6.994 6.970 6.945 6.920 6.894 6.869 6.864 6.792 6.767 6.715 6.715 6.688 6.662 6.635 6.609 6.555	Dep. 5.664 5.694 5.725 5.755 5.815 5.815 5.845 5.905 5.934 5.993 6.022 6.080 6.109 6.109 6.167	502 504 504 504 494 494 494 484 484 484 474 474 474 474 474 477 464
394 394 394 394 404 404 414 414 414 424 424 424 424 424 424 42	Dep. 3.147 3.164 3.180 3.197 3.214 3.231 3.264 3.297 3.313 3.329 3.334 3.340 3.410 3.426	Lat. 4.663 4.646 4.630 4.613 4.596 4.579 4.545 4.521 4.494 4.476 4.4459 4.441 4.426 4.388 4.370 4.352	Dep. 3.776 3.796 3.816 3.837 3.857 3.877 3.917 3.936 3.976 3.956 3.976 4.014 4.034 4.073 4.092 4.111 4.130	Lat. 5.440 5.421 5.401 5.382 5.362 5.362 5.363 5.263 5.263 5.263 5.202 5.182 5.140 5.119 5.078	Dep. 4.405 4.425 4.453 4.476 4.500 4.523 4.546 4.569 4.569 4.615 4.638 4.661 4.684 4.707 4.722 4.774 4.792 4.774 4.792 4.7818	Lat. 6.217 6.195 6.175 6.195 6.151 6.128 6.106 6.083 6.061 6.035 6.061 5.992 5.964 5.992 5.585 5.875 5.851 5.827 5.803	Dep. 5.035 5.062 5.089 5.116 5.142 5.169 5.196 5.222 5.285 5.301 5.379 5.456 5.430 5.456 5.456 5.456	Lat. 6.994 6.970 6.945 6.920 6.894 6.869 6.844 6.818 6.792 6.767 6.715 6.688 6.662 6.635 6.635 6.609 6.582 6.555	Dep. 5.664 5.694 5.755 5.785 5.815 5.875 5.934 5.964 5.964 6.022 6.051 6.080 6.138 6.167 6.195	502 503 504 504 509 493 494 494 484 484 473 473 473 473 463 464
391 391 391 391 401 401 401 411 411 421 421 421 421 421 421 421 431 431 431 440	Dep. 3.147 3.164 3.180 3.197 3.214 3.2247 3.264 3.280 3.297 3.313 3.329 3.329 3.3346 3.362 3.374 3.410 3.442 3.458 3.473	Lat. 4.663 4.6460 4.630 4.613 4.596 4.545 4.545 4.521 4.494 4.459 4.441 4.406 4.388 4.370 4.352 4.3316	Dep. 3.776 3.796 3.816 3.816 3.837 3.857 3.897 3.995 4.015 4.034 4.073 4.092 4.111 4.130 4.148	Lat. 5.440 5.421 5.481 5.382 5.362 5.362 5.383 5.283 5.283 5.263 5.263 5.263 5.261 5.140 5.119 5.078 5.057 5.035	Dep. 4.405 4.425 4.453 4.476 4.500 4.524 4.546 4.569 4.661 4.684 4.729 4.752 4.7752 4.7752 4.7796 4.818 4.848	6.217 6.195 6.175 6.151 6.128 6.106 6.083 6.061 6.035 5.992 5.968 5.945 5.992 5.875 5.803 5.755	Dep. 5.035 5.069 5.089 5.116 5.142 5.169 5.228 5.275 5.301 5.353 5.379 5.430 5.440 5.481 5.507 5.557	1.at. 6.994 6.9745 6.920 6.894 6.894 6.818 6.792 6.767 6.741 6.715 6.688 6.6635 6.609 6.555 6.528 6.504	Dep. 5.664 5.694 5.725 5.725 5.785 5.815 5.845 5.905 5.934 5.964 5.993 6.022 6.051 6.109 6.1367 6.195 6.252	507 508 508 509 509 498 498 498 488 488 478 471 471 471 468 468 468 468 468 468 468 468 468 468
391 391 391 401 401 401 411 411 412 421 421 431 431 431 441	Dep. 3.147 3.164 3.180 3.197 3.214 3.231 3.247 3.264 3.280 3.293 3.313 3.313 3.329 3.346 3.378 3.378 3.340 3.442 3.458 3.442 3.458	Lat. 4.663 4.630 4.613 4.596 4.562 4.545 4.511 4.494 4.476 4.459 4.388 4.370 4.334 4.316 4.398	Dep. 3.776 3.776 3.776 3.776 3.816 3.837 3.857 3.897 3.936 3.936 3.956 3.956 4.015 4.054 4.054 4.074 4.130 4.149 4.168	Lat. 5.440 5.421 5.362 5.362 5.362 5.362 5.283 5.283 5.283 5.283 5.282 5.161 5.119 5.098 5.077 5.035 5.014	Dep. 4.405 4.423 4.476 4.5023 4.523 4.546 4.506 4.509 4.615 4.638 4.661 4.684 4.707 4.729 4.774 4.794 4.794 4.794 4.794 4.794 4.794 4.794 4.841 4.848	6.217 6.173 6.173 6.151 6.128 6.106 6.083 6.016 6.038 6.015 5.992 5.968 5.942 5.851 5.851 5.851 5.851 5.873 5.779 5.730	Dep. 5.035 5.062 5.089 5.116 5.142 5.169 5.248 5.275 5.327 5.337 5.430 5.456 5.456 5.456 5.456 5.532 5.552 5.552	1.at. 6.994 6.970 6.942 6.894 6.864 6.818 6.792 6.741 6.716 6.741 6.716 6.688 6.662 6.609 6.582 6.509 6.528 6.501 6.447	Dep. 5.664 5.694 5.725 5.725 5.755 5.815 5.845 5.895 5.993 6.021 6.080 6.138 6.161 6.138 6.161 6.195 6.224 6.224 6.220	50° 50° 50° 49° 49° 48° 48° 47° 46° 46° 46° 46° 46° 46° 46° 46° 46° 46
39° 394 394 40° 404 404 414 414 424 424 436 436 4414 444	Dep. 3.147 3.164 3.180 3.197 3.214 3.231 3.247 3.264 3.280 3.393 3.342 3.378 3.378 3.378 3.410 3.442 3.458 3.473 3.489 3.505	Lat. 4.663 4.630 4.613 4.579 4.562 4.545 4.511 4.476 4.476 4.441 4.424 4.406 4.388 4.370 4.334 4.316 4.298 4.298 4.261	Dep. 3.776 3.776 3.786 3.816 3.837 3.857 3.897 3.996 3.995 4.015 4.034 4.073 4.092 4.111 4.130 4.148 4.187 4.224	Lat. 5.440 5.421 5.382 5.383 5.323 5.323 5.223 5.222 5.202 5.182 5.160 5.119 5.078 5.057 5.035 5.014 4.993	Dep. 4.405 4.423 4.453 4.476 4.502 4.546 4.592 4.615 4.638 4.661 4.684 4.707 4.729 4.774 4.792 4.774 4.788 4.848 4.848 4.848 4.848 4.848 4.848 4.848 4.892	6.217 6.195 6.173 6.151 6.126 6.083 6.061 6.038 6.015 5.992 5.968 5.945 5.945 5.875 5.875 5.803 5.755 5.730 5.730 6.681	Dep. 5.035 5.069 5.089 5.116 5.169 5.169 5.222 5.275 5.327 5.357 5.456 5.456 5.456 5.557 5.552 5.632	1.at. 6.994 6.975 6.945 6.920 6.8849 6.864 6.867 6.715 6.662 6.662 6.635 6.582 6.528 6.501 6.447 6.447 6.447 6.492	Dep. 5.664 5.694 5.725 5.755 5.7815 5.845 5.845 5.905 5.993 6.021 6.080 6.138 6.161 6.195 6.252 6.280 6.336	507 508 508 508 509 498 498 498 488 488 478 471 471 471 466 466 466 468 468 468 468 468 468
394 394 394 394 404 404 404 414 414 414 424 424 424 434 434 434 434 434 444	Dep. 3.147 3.164 3.189 3.197 3.214 3.2247 3.2640 3.297 3.313 3.329 3.346 3.362 3.378 3.394 3.426 3.4428 3.453 3.453 3.453 3.453 3.453	Lat. 4.663 4.646 4.630 4.613 4.596 4.545 4.545 4.545 4.541 4.494 4.476 4.459 4.444 4.406 4.370 4.352 4.331 4.316 4.290	Dep. 3.776 3.796 3.796 3.816 3.837 3.857 3.897 3.995 4.015 4.034 4.073 4.093 4.111 4.130 4.149 4.168 4.187 4.206	Lat. 5.440 5.420 5.421 5.362 5.362 5.362 5.363 5.283 5.283 5.283 5.222 5.182 5.180 5.140 5.199 5.078 5.057 5.035 5.014 993	Dep. 4.405 4.429 4.453 4.476 4.500 4.523 4.546 4.592 4.615 4.681 4.684 4.772 4.772 4.772 4.774 4.883 4.883 4.8863 4.893	6.217 6.195 6.151 6.128 6.106 6.083 6.061 6.03 6.061 5.998 5.945 5.945 5.988 5.875 5.827 5.827 5.827 5.827 5.755 5.755 5.736	Dep. 5.035 5.069 5.089 5.116 5.142 5.169 5.224 5.275 5.327 5.353 5.379 5.405 5.430 5.4481 5.557 5.552 5.567	1.at. 6.994 6.945 6.945 6.894 6.894 6.864 6.818 6.792 6.767 6.715 6.688 6.662 6.635 6.609 6.555 6.528 6.502 6.474 6.419	Dep. 5.664 5.694 5.725 5.725 5.785 5.815 5.845 5.905 5.934 6.022 6.051 6.080 6.109 6.109 6.167 6.194 6.252 6.252 6.308	50° 50° 50° 49° 49° 48° 48° 47° 46° 46° 46° 46° 46° 46° 46° 46° 46° 46

SQUARES, CUBES, SQUARE AND CUBE ROOTS, CIRCUMFERENCES, AND AREAS.

No.	Square.	Cube.	Sq. Root.	Cu. Root.	Reciprocal.	Circum.	Area.
1	1	1	1.0000	1.0000	.100000000	3.1416	0.7854
23 4 5 6 7 8	4	8	1.4142	1.2599	.5000000000	6.2832	3.1416
3	9	27	1.7321	1.4422	.333333333	9.4248	7.0686
4	16	64	2.0000	1.5874	.250000000	12.5664	12.5664
5	2 5	125	2.2361	1.7100	.200000000	15.7080	19.635
7	36 49	216 343	2.4495	1.8171	.166666667	18.850	28.274
6	64	512	2.6458 2.8284	1.9129 2.0000	.142857143	21.991 25.133	38.485 50.266
9	81	729	3.0000	2.0801	.111111111	28.274	63.617
10	100	1,000	3.1623	2.1544	.100000000	31.416	78.540
ii	121	1,331	3.3166	2.2240	.090909091	34.558	95.033
12	144	1,728	3.4641	2.2894	.083333333	37.699	113.10
13	169	2,197	3.6056	2.3513	.076923077	40.841	132.73
14	196	2,744	3.7417	2.4101	.071428571	43.982	153.94
15	225	3,375	3.8730	2.4662	.066666667	47.124	176.71
16	256	4,096	4.0000	2.5198	.062500000	50.265	201.06
17	289	4,913	4.1231	2.5713	.058823529	53.407	226.98
18	324	5,832	4.2426	2.6207	.05555556	56.549	254.47
19	361	6,859	4.3589	2.6684	.052631579	59.690	283.53
20 21	400 441	8,000	4.4721 4.5826	2.7144 2.7589	.050000000	62.832 65.973	314.16 346.36
22	484	9,261 10,648	4.6904	2.7389	.047619048	69.115	380.13
23	529	12,167	4.7958	2.8439	.043478261	72.257	415.48
24	576	13,824	4.8990	2.8845	.041666667	75.398	452.39
25	625	15,625	5.0000	2.9240	.040000000	78.540	490.87
26	676	17,576	5.0990	2.9625	.038461538	81.681	530.93
27	729	19,683	5.1962	3.0000	.037037037	84.823	572.56
28	784	21,952	5.2915	3.0366	.035714286	87.965	615.75
29	841	24,389	5.3852	3.0723	.034482759	91.106	660.52
30	900	27,000	5.4772	3.1072	.033333333	94.248	706.86
31	961	29,791	5.5678	3.1414	.032258065	97.389	754.77
32	1,024	32,768	5.6569	3.1748	.031250000	100.53	804.25
33	1,089	35,937	5.7446	3.2075	.030303030	103.67	855.30 907.92
34 35	$1,156 \\ 1,225$	39,304 42,875	5.8310 5.9161	3.2396 3.2717	.029411765	106.81 109.96	962.11
36	1,226	46,656	6.0000	3.3019	.027777778	113.10	1.017.88
37	1,369	50,653	6.0828	3.3322	.027027027	116.24	1.075.21
38	1,444	54,872	6.1644	3.3620	.026315789	119.38	1,134.11
39	1,521	59,319	6.2450	3.3912	.025641026	122.52	1,194.59
40	1,600	64,000	6.3246	3.4200	.025000000	125.66	1,256.64
41	1,681	68,921	6.4031	3.4482	.024390244	128.81	1,320.25
42	1,764	74,088	6.4807	3.4760	.023809524	131.95	1,385.44
43	1,849	79,507	6.5574	3.5034	.023255814	135.09	1,452.20
44	1,936	85,184	6.6332	3.5303	.022727273	138.23	1,520.53
45	2,025	91,125	6.7082	3.5569	.022222222	141.37 144.51	1,590.43
46	$2,116 \\ 2,209$	97,336	6.7823 6.8557	3.5830 3.6088	.021739130 .021276600	144.51	1,661.90 1,734.94
47	2,209	103,823	6.9282	3.6342	.020833333	150.80	1,809.56
48 49	2,304	110,592 117,649	7.0000	3.6593	.020408163	153.94	1,885.74
50	2,500	125,000	7.0711	3.6840	,020000000	157.08	1,963.50
51	2,601	132,651	7.1414	3.7084	.019607843	160.22	2,042.8 2
52	2,704	140,608	7.2111	3.7325	.019230769	163,36	2,123.72
53	2,809	148,877	7.2801	3.7563	.018867925	166.50	2,206.18
54	2,916	157,464	7.3485	3.7798	.018518519	169.65	2,290.22
55	3.025	166,375	7.4162	3.8030	.018181818	172.79	2,375.83
				1		<u> </u>	

No.	Square.	Cube.	Sq. Root.	Cu. Root.	Reciprocal.	Circum	Area
56	3,136	175,616	7.4833	3.8259	.017857143	175.93	2,463.0
57 58	3,249 3,364	185,193 195,112	7.5498 7.6158	3.8485 3.8709	.017543860 .017241379	179.07 182.21	2,551.7 2,642.0
59	3,481	205,379	7.6811	3.8930	.016949153	185.35	2,733.
60	3,600	216,000	7.7460	3.9149	.016666667	188.50	2,827.4
61	3,721	226,981	7.8102	3.9365	.016393443	191.64	2,922.4
62	3,844	238,328	7.8740	3.9579	.016129032	194.78	3,019.0
63	3,969	250,047	7.9373	3.9791	.015873016	197.92	3,117.2
64	4,096	262,144	8.0000	4.0000	.015625000	201.06	3,216.9
65 66	4,225 4,356	274,625	8.0623	4.0207	.015384615 .015151515	204.20 207.34	3,318.3
67	4,336	287,496 300,763	8.1240 8.1854	4.0412 4.0615	.014925373	210.49	3,421.1 3,525.6
68	4,624	314,432	8.2462	4.0817	.014705882	213.63	3,631.6
69	4,761	328,509	8.3066	4.1016	.014492754	216.77	3,739.2
70	4,900	343,000	8.3666	4.1213	.014285714	219.91	3,848.4
71	5,041	357,911	8.4261	4.1408	.014084517	223.05	3,959.1
72	5,184	373,248	8.4853	4.1602	.013888889 .013698630	226.19 229.34	4,071.5
73 74	5,329 5,476	389,017 405,224	8.5440 8.6023	4.1793 4.1983	.013513514	232.48	4,185.3 4,300.8
75	5,625	421,875	8.6603	4.2172	.013333333	235.62	4,417.8
76	5,776	438,976	8.7178	4.2358	.013157895	238.76	4,536.
77	5,929	456,533	8.7750	4.2543	.012987013	241.90	4,656.
78	6,084	474,552	8.8318	4.2727	.012820513	245.04	4,778.
79 80	6,241 6,400	493,039	8.8882 8.9443	4.2908 4.3089	.012658228 .012500000	248.19 251.33	4,901. 5,026.
81	6,561	512,000 581,441	9.0000	4.3267	.012345679	254.47	5,153.
82	6,724	551,368	9.0554	4.3445	.012195122	257.61	5,281.
83	6,889	571,787	9.1104	4.3621	.012048193	260.75	5,410.
84	7,056	592,704	9.1652	4.3795	.011904762	263.89	5,541.
85 86	7,225	614,125	9.2195 9.2736	4.3968 4.4140	.011764706 .011627907	267.04 270.18	5,674. 5,808.
87	7,396 7,569	636,056 658,503	9.2730	4.4310	.011494253	273.32	5,944.
88	7,744	681,472	9.3808	4.4480	.011363636	276.46	6,082.
89	7,921	704,969	9.4340	4.4647	.011235955	279.60	6,221.
90	8,100	729,000	9.4868	4.4814	.011111111	282.74	6,361.
91	8,281	753,571	9.5394	4.4979	.010989011	285.88 289.03	6,503.
92 93	8,464 8,649	778,688 804,357	9.5917 9.6437	4.5144 4.5307	.010869565 .010752688	292.17	6,647. 6,792.
94	8,836	830,584	9.6954	4.5468	.010638298	295.31	6,939.
95	9,025	857,375	9.7468	4.5629	.010526316	298.45	7,088.
96	9,216	884,736	9.7980	4.5789	.410416667	301.59	7,238.
97	9,409	912,673	9.8489	4.5947	.010309278	304.73	7,389.
98 99	9,604 9,801	941,192 970,299	9.8995 9.9499	4.6104 4.6261	.010204082 .010101010	307.88	7,542.9
00	10,000	1,000,000	10.0000	4.6416	.010000000	314.16	7,853.
ŏĭ	10,201	1,030,301	10.0499	4.6570	.009900990	317.30	8,011.8
02	10,404	1,061,208	10.0995	4.6723	.009803922	320.44	8,171.2
03	10,609	1,092,727	10.1489	4.6875	.009708738	323.58	8,332.2
04	10,816	1,124,864	10.1980	4.7027	.009615385	326.73 329.87	8,494.8
05 06	11,025 11,236	1,157,625 $1,191,016$	10.2470 10.2956	4.7177 4.7326	.009523810	333.01	8,659.0 8,824.7
07	11,449	1,225,043	10.3441	4.7475	.009345794	336.15	8,992.0
08 ·	11,664	1.259.712	10.3923	4.7622	.009259259	339.29	9,160.8
09	11,881	1,295,029	10.4403	4.7769	.009174312	342.43	9,331.3
10	12,100	1,331,000	10.4881	4.7914	.009090909	345.58	9,503.3
11	12,321	1,367,631	10.5357	4.8059	.009009009	348.72	9,676.8
12	12,544	1,404,928	10.5830	4.8203	.008928571	351.86	9,852.0
13 14	12,769 12,996	1,442,897 1,481,544	10.6301 10.6771	4.8346 4.8488	.008849558 .008771930	355.00 358.14	10,028.7
15	13,225	1,520,875	10.7238	4.8629	.008695652	361.28	10,386.8
16	13,456	1,560,896	10.7703	4.8770	.008020690	364.42	10,568.3 10,751.3
17	13,689	1,601,613	10.8167	4.8910	.008547009	367.57	

			1		1	. 	
No.	Square.	Cube.	Sq. Root.	Cu. Root.	Reciprocal.	Circum.	Area.
119	14,161	1,685,159	10.9087	4.9187	.008403361	373.85	11,122.02
120 121	14,400	1.728.000	10.9545	4.9324	.008333333	376.99	11,309.73
121	14,641	1,771,561	11.0000	4.9461	.008264463	380.13	11,499.01
122	14,834	1,815,848	11.0454	4.9597	.008196721	383.27	11,689.87
123 124	15,129 15,376	1,860,867 1,906,624	11.0905 11.1355	4.9732 4.9866	.008130081 .008064516	386.42 389.56	11,882.29 12,076.28
125	15,625	1,953,125	11.1803	5.0000	.008000000	392.70	12,271.85
126	15.876	2,000,376	111.2250	5.0133	.007936508	395.84	12,468.98
127	16,129	2,048,383	11.2694	5.0265	.007874016	398.98	12,667.69
128	16,129 16,384	2,097,152	11.3137	5.0397	.007812500	402.12 405.27	12,867.96
129	16,641	2,146,689	11.3578	5.0528	.007751938	405.27	13,069.81
130	16,900	2,197,000	11.4018	5.0658	.007692308	408.41	13,273.23
131 132	17,161 1 7,4 24	2,248,091 2,299,968	11.4455 11.4891	5.0788 5.0916	.007633588	411.55 414.69	13,478.22 13,684.78
133	17,689	2,352,637	11.5326	5.1045	.007518797	417.83	13,892.91
134	17,956	2,406,104	11.5758	5.1172	.007462687	420.97	14,102.61
135	17,956 18,225	2,460,375	11.6190	5.1299	.007407407	424.12	14,313.88
136	18,496	2,515,456	11.6619	5.1426	.007352941	427.26	14,526.72
137	18,769	2,571,353	11.7047	5.1551	.007299270	430.40	14,741.14
138 139	19,044 19,321	2,628,072 2,685,619	11.7473	5 1676 5.1801	.007246377	433.54 436.68	14,957.12 15,174.68
140	19,600	2,744,000	11.8322	5.1925	.007142857	439.82	15,393.80
141	19,881	2,803,221	11.8743	5.2048	.007092199	442.96	15,614.50
142	20,164	2,863,288	11.9164	5.2171	.007042254	446.11	15,836.77
143	20,449	2,924,207	11.9583	5.2293	.006993007	449.25	16,060.61
144	20,736	2,985,984	12.0000	5.2415	.006944444	452.39	16,286.02
145 146	21,025 21,316	3,048,625	12.0416 12.0830	5.2536 5.2656	.006896552 .006849315	455.53 458.67	16,513.00 16,741.55
147	21,609	3,112,136 3 176 523	12.1244	5.2776	.006802721	461.81	16 971 67
148	21,904	3.241.792	12.1655	5.2896	.006756757	464.96	16,971.67 17,203.36
149	21,904 22,201	3,176,523 3,241,792 3,307,949	12.2066	5.3015	.006711409	468.10	17,436.62
150	22,500	3,375,000	12.2474	5.3133	.006666667	471.24	17,671.46
151	22,801	3,442,951	12.2882	5.3251	.006622517	474.38	17,907.86
152 153	23,104 23,409	3,511,008 3,581,577	12.3288 12.3693	5.3368 5.3485	.006578947 .006535948	477.52 480.66	18,145.84 18,385.39
154	23,716	3.652.264	12.4097	5.3601	.006493506	483.81	18,626.50
155	24,025	3,723,875	12.4499	5.3717	.006451613	486.95	18,869.19
156	24,336	3,652,264 3,723,875 3,796,416	12.4900	5.3832	.006410256	490.09	19,113.45
157	24,649	3,869,893	12.5300	5.3947	.006369427	493.23	19,359.28
158 159	24,964 25,281	3,944,312	12.5698	5.4061	.006329114	496.37	19,606.68
160	25,600	4,019,679 4,096,000	12.6095 12.6491	5.4175 5.4288	.006289308	499.51 502.65	19,855.65 20,106.19
161	25.921	4,173,281	12.6886	5.4401	.006211180	505.80	20,358.31
162	26,244	4,251,528	12.7279	5.4514	.006172840	508.94	20,611.99
163	26,569	4,330,747	12.7671	5.4626	.006134969	512.08	20,867.24
164	26,896	4,410,944	12.8062	5.4737	.006097561	515.22	21,124.07
165 166	27,225 27,556	4,492,125	12.8452 12.8841	5.4848 5.4959	.006060606	518.36	21,382.46
167	27,889	4,574,296 4,657,463	12.8641	5.5069	.006024096	521.50 524.65	21,642.43 21,903.97
168	28,224	4,741,632	12.9615	5.5178	.005952381	527.79	22,167.08
169	28,224 28,561	4,826,809	13.0000	5.5288	.005917160	530.93	22,431.76
170	28,900	4,913,000	13.9384	5.5397	.005882353	534.07	22,698.01
171	29,241	5,000,211	13.0767	5.5505	.005847953	537.21	22,965.83
172 173	28,584 29,929	5,088,448 5,177,717	13.1149 13.1529	5.5613 5.5721	.005813953 .005780347	540.35 543.50	23,235.22 23,506.18
174	30,276	5,268,024	13.1909	5.5828	.005747126	545.50 546.64	23,778.71
175	30,625	5,359,375	13.2288	5.5934	.005714286	549.78	24,052.82
176	30,976	5,359,375 5,451,776	13.2665	5.6041	.005681818	552.92	24,328.49
177	31,329	5,545,233	13.3041	5.6147	.005649718	556.06	24,605.74
178	31,684	5,639,752	13.3417	5.6252	.005617978	559.20	24,884.56
179 180	32,041 32,400	5,735,339 5,832,000	13.3791 13.4164	5.6357 5.6462	.005586592	562.35 565.49	25,164.94 25,446.90
181	32,761	5,929,741	13.4536	5.6567	.005524862	568.63	25,730.43
1		5,5=5,	1 -0.2000	3.0.01	.550022002	30.7.1	-5,

No.	Square.	Cube.	Sq. Root.	Cu. Root.	Reciprocal.	Circum.	Area.
182	33,124	6,028,568	13.4907	5.6671	.005494505	571.77	26,015.53
183	33,489	6,128,487	13.5277	5.6774	.005464481	574.91	26,302.20
184	33,856	6,229,504	13.5647	5.6877	.005434783	578.05	26,590.44
185	34,225	6,331,625	13.6015	5.6980	.005405405	581.19	26,880.25
186	34,596	6,434,856	13.6382	5.7083	.005376344	584.34	27,171.63
187	34,969	6,539,203	13.6748	5.7185	.005347594	587.48	27,464.59
188 189	35,344 35,721	6,644,672 6,751,269	13.7113 13.7477	5.7287 5.7388	.005319149 .005291005	590.62 593.76	27,759.11 28,055.21
190	36,100	6,859,000	13.7840	5.7489	.005263158	596.90	28,352.87
191	36,481	6,967,871	13.8203	5.7590	.005235602	600.04	28,652.11
192	36,864	7,077,888	13.8564	5.7690	.005208333	603.19	28,952.92
193	37,249	7,189,017	13.8924	5.7790	.005181347	606.33	29,255.30
194	37,636	7,301,384	13.9284	5.7890	.005154639	609.47	29,559.25
195	38,025	7,414,875	13.9642	5.7989	.005128205	612.61	29,864.77
196	38,416	7,529,536	14.0000	5.8088	.005102041	615.75	30,171.86
197	38,809	7,645,373	14.0357	5.8186	.005076142	618.89	30,480.52
198 199	39,204	7,762,392 7,880,599	14.0712	5.8285 5.8383	.005050505 .005025126	622.04 625.18	30,790.75
200	39,601 40,000	8,000,000	14.1067 14.1421	5.8480	.005000000	628.32	31,102.55 31,415.93
201	40,401	8,120,601	14.1774	5.8578	.004975124	631.46	31,730.87
202	40,804	8,242,408	14.2127	5.8675	.004950495	634.60	32,047.39
203	41,209	8,365,427	14.2478	5.8771	.004926108	637.74	32,365.47
204	41,616	8,489,664	14.2829	5.8868	.004901961	640.88	32,685.13
205	42,025	8,615,125	14.3178	5.8964	.004878049	644.03	33,006.36
206	42,436	8,741,816	14.3527	5.9059	.004854369	647.17	33,329.16
207	42,849	8,869,743	14.3875	5.9155	.004830918	650.31	33,653 .53
208	43,264	8,998,912	14.4222	5.9250	.004807692	653.45	33,979.47
209 210	43,681 44,100	9,129,329 9,261,000	14.4568 14.4914	5.9345 5.9439	.004784689	656.59 659.73	34,306.98
211	44,521	9,393,931	14.5258	5.9533	.004739336	662.88	34,636.06 34,966.71
212	44,944	9,528,128	14.5602	5.9627	.004716981	666.02	35,298,94
213	45,369	9,663,597	14.5945	5.9721	.004694836	669.16	35,632,73
214	45,796	9,800,344	14.6287	5.9814	.004672897	672.30	35,968,09
215	46,225	9,938,375	14.6629	5.9907	.004651163	675.44	36,305.03
216	46,656	10,077,696	14.6969	6.0000	.004629630	678.58	36,643.54
217	47,089	10,218,313	14.7309	6.0092	.004608295	681.73	36,983.61
218	47,524	10,360,232	14.7648	6.0185	.004587156	684.87	37,325.26
$\frac{219}{220}$	47,961	10,503,459 10,648,000	14.7986 14.8324	6.0277 6.0368	.004566210 .004545455	688.01 691.15	37,668.48
221	48,400 48,841	10,793,861	14.8661	6.0459	.004524887	694.29	38,013.27 38,359.63
222		10,941,048	14.8997	6.0550	.004504505	697.43	38,707.56
223	49,284 49,729	11,089,567	14.9332	6.0641	.004484305	700.58	39,057.07
224	50,176	11,239,424	14.9666	6.0732	.004464286	703.72	39,408.14
225	50,625	11,390,625	15.0000	6.0822	.004444444	706.86	39,760.78
226	51,076	11,543,176	15.0333	6.0912	.004424779	710.00	40,115.00
227	51,529	11,697,083	15.0665	6.1002	.004405286	713.14	40,470.78
228 229	51,984	11,852,352	15.0997	6.1091	.004385965	716.28	40,828.14
229 230	52,441 52,900	12,008,989 12,167,000	15.1327 15.1658	6.1180 6.1269	.004366812 .004347826	719.42 722.57	41,187.07
231	53,361	12,326,391	15.1987	6.1358	.004329004	725.71	41,547.56 41,909.63
232	53,824	12,487,168	15.2315	6.1446	.004310345	728.85	42,273.27
233	54,289	12,649,337	15.2643	6.1534	.004291845	731.99	42,638.48
234	54,756	12,812,904	15.2971	6.1622	.004273504	735.13	43,005.26
235	55,225	12,977,875	15.3297	6.1710	.004255319	738.27	43,373.61
236	55,696	13,144.256	15.3623	6.1797	.004237288	741.42	43,743.54
237	56,169	13,312,053	15.3948	6.1885	.004219409	744.56 747.70	44,115.03
238	56,644	13,481,272	15.4272	6.1672	.004201681	747.70	44,488.09
239 240	57,121 57,600	13,651,919 13,824,000	15.4596 15.4919	6.2058 6.2145	.004184100	750.84 753.98	44,862.73
241	57,600 58,081	13,997,521	15.4919	6.2231	.004166667 .004149378	757.12	45,238.93 45,616.71
242	58,564	14,172,488	15.5563	6.2317	.004132231	760.27	45,996.06
243	59,049	14,348,907	15.5885	6.2403	.004115226	763.41	46,876.98
244	59,536	14,526,784	15.6205	6.2488	.004098361	766.55	46,759.47

No.	Square.	Cube.	Sq. Root.	Cu. Root.	Reciprocal.	Circum.	Area.
245	60,025	14,706,125	15.6525	6.2573	.004081633	769.69	47,143.52
246	60,516	14,886,936	15.6844	6.2658	.004065041	772.83	47,529.16
247	61,009	15,069,223	15.7162	6.2743	.004048583	775.97	47,916.36
248	61,504	15,252,992	15.7480	6.2828	.004032258	779.11	48,305.13
249	62,001	15,438,249	15.7797	6.2912	.004016064	782.26	48,695.47
250	62,500	15,625,000	15.8114	6.2996	.004000000	785.40	49.087.39
251	6 3,001	15,813,251	15.8430	6.3080	.003984064	788.54	49,480.87
252	63,504	16,003,008	15.8745	6.3164	.003968254	791.68	49,875.92
253	64,009	16,194,277	15.9060	6.3247	.003952569	794.82	50,272.55
254	64,516	16,387,064	15.9374	6.3330	.003937008	797.96	50,670.75
255 256	6 5,025	16,581,375 16,777,216	15.9687	6.3413 6.3496	.003921569 .003906250	801.11 804.25	51,070.52 51,471.85
	65,536	16,777,210	16.0000		.003891051	807.39	
257 258	66,049 66,564	16,974,593 17,173,512	16.0312 16.0624	6.3579 6.3661	.003875969	810.53	51,874.76 52,279.24
259	67,081	17,373,979	16.0935	6.3743	.003861004	813.67	52,685.29
260	67,600	17,576,000	16.1245	6.3825	.003846154	816.81	53,092.92
261	68,121	17,779,581	16,1555	6.3907	.003831418	819.96	53,502.11
262	68,644	17,984,728	16.1864	6,3988	.003816794	823.10	53,912.87
263	69,169	18,191,447	16.2173	6.4070	.003802281	826.24	54,325.21
264	69,696	18,399,744	16.2481	6.4151	.003787879	829.38	54,739.11
265	70,225	18,609,625	16.2788	6.4232	.003773585	832.52	55,154.59
266	70,756	18,821,096	16.3095	6.4312	.003759398	835.66	55,571.63
267	71,289	19,034,163	16.3401	6.4393	.003745318	838.81	55,990.25
268	71,824	19,248,832	16.3707	6.4473	.003731343	841.95	56,410.44
269	72,361	19,465,109	16.4012	6.4553	.003717472	845.09	56,832.20
270	72,900	19,683,000	16.4317	6.4633	.003703704	848.23	57,255.53
271	73,441	19,902,511	16.4621	6.4713	.003690037	851.37	57,680.43
272	73,984	20,123,643 20,346,417	16.4924 16.5227	6.4792 6.4872	.003676471	854.51 857.65	58,106.90 58,534.94
273 274	74,529 75,076	20,540,417	16.5529	6.4951	.003649635	860.80	58,964.55
275	75,625	20,796,875	16.5831	6.5030	.003636364	863.94	59,395.74
276	76,176	21,024,576	16.6132	6.5108	.003623188	867.08	59,828.49
277	76,729	21,253,933	16.6433	6.5187	.003610108	870.22	60,262.82
278	77,284	21,484,952	16.6783	6.5265	.003597122	873.36	60,698.71
279	77,841	21,717,639	16.7033	6.5343	.003584229	876.50	61,136.18
280	78,400	21,952,000	16.7332	6.5421	.003571429	879.65	61,575.22
281	78,961	22,188,041	16.7631	6.5499	.003558719	882.79	62,015.82
282	79,524	22,425,768	16.7929	6.5577	.003546099	885.93	62,458.00
283	80,089	22,665,187	16.8226	6.5654	.003533569	889.07	62,901.75
284	80,656	22,906,304	16.8523	6.5731	.003522127	892.21	63,347.07
285	81,225	23,149,125	16.8819	6.5808	.003508772	895.35	63,793.97
286 287	81,796 82,369	23,393,656	16.9115 16.9411	6.5885 6.5962	.003496503	898.50 901.64	64,242.43 64,692.46
288	82,944	23,639,903 23,887,872	16.9706	6.6039	.003472222	904.78	65,144.07
289	83,521	24,137,569	17.0000	6.6115	.003460208	907.92	65,597.24
290	84,100	24,389,000	17.0294	6.6191	.003448276	911.06	66,051.99
291	84,681	24,642,171	17.0587	6.6267	.003436426	914.20	66,508.30
292	85,264	24,897,088	17.0880	6.6343	.003424658	917.35	66,966.19
293	85,849	25,153,757	17.1172	6.6419	.003412969	920.49	67,425.65
294	86,436	25,412,184	17.1464	6.6494	.003401361	923.63	67,886.68
295	87,025	25,672,375	17.1756	6.6569	.003389831	926.77	68,349.28
296	87,616	25,934,836	17.2047	6.6644	.003378378	929.91	68,813.45
297	88,209	26,198,073	17.2337	6.6719	.003367003	933.05	69,279.19
1 298	88,804	26,463,592	17.2627	6.6794	.003355705	936.19	69,746.50
299	89,401	26,730,899	17.2916	6.6869	.003344482	939.34 942.48	70,215.38
300	90,000	27,000,000	17.3205 17.3494	6.6943	.003333333	942.48 945.62	70,685.83
301 302	90,601 91,204	27,270,901 27,543,608	17.3781	6.7018 6.7092	.003311258	948.76	7 1,157.86 71,6 31.45
303	91,809	27,818,127	17.4069	6.7166	.003301330	951.90	72,106.62
304	92,416	28,094,464	17.4356	6.7240	.003289474	955.04	72,583.36
305	93,025	28,372,625	17.4642	6.7313	.003278689	958.19	73,061.66
306	93,636	28,652,616	17.4929	6.7387	.003267974	961.33	73,541.54
307	94,249	28,934,443	17.5214	6.7460	.003257329	964.47	74,022.99

309 95,481 29,508,629 17,5784 6,7606 0032926-16 970,75 74,990.6 311 96,100 29,791,000 17,6068 6,7679 0032259-66 973,89 75,476.7 311 96,721 30,080,231 17,6352 6,7752 .003215434 977.04 75,964.5 312 97,344 30,871,328 17,6635 6,7894 .003205128 980,18 76,483.8 314 98,596 30,959,144 17,7200 6,7969 .003174603 989,06 77,497.1 316 99,856 31,255,875 17,7482 6,8041 .003174603 989,06 7,497.1 317 100,489 31,855,013 17,8046 6,8185 .003144574 998,86 78,922.8 318 101,761 32,461,759 17,8856 6,8396 .003125000 1,002,17 79,922.9 320 102,400 32,768,000 17,8855 6,8399 .003125000 1,006,31 80,422.2 322 104,976								
1909 95,481 29,506,629 17,5784 6,7666 0,002326306 973,75 74,990,8310 96,100 29,791,000 17,6088 6,7769 0,002325806 973,87 75,476.7 311 96,721 30,080,231 17,6852 6,7762 0,002315434 977,04 75,964,5 311 96,721 30,080,231 17,6852 6,7762 0,003215434 977,04 75,964,5 311 98,596 30,969,144 17,7200 6,7999 0,003184718 98,596 30,969,144 17,7200 6,7999 0,003184718 986,46 77,437.1 316 99,856 31,554,496 17,77842 6,8041 0,03174603 999,07 77,981.1 317 100,489 31,855,018 17,8045 6,8155 0,00318457 995,88 78,923.8 318 101,124 32,157,432 17,8066 6,8256 0,0314654 999,08 79,422.6 319 101,761 32,461,759 17,8666 6,8256 0,0314654 999,08 79,422.6 322 103,684 33,386,248 17,9444 6,8541 0,03115265 1,008,46 80,9242 322 103,684 33,386,248 17,9444 6,8541 0,03016590 1,011,59 81,433.2 323 104,976 34,012,224 18,0000 6,8683 0,03096420 1,017,88 80,9242 322 106,6276 34,645,976 18,0556 6,8824 0,03007485 1,024,16 83,468, 32 106,276 34,645,976 18,1084 6,904 0,03038104 1,027,30 33,935,000 18,189 18,1894 6,904 0,03038104 1,027,30 33,935,000 18,189 10,000 33,000,000 33,000,000 30,0	No.	Square.	Cube.	Sq. Root.	Cu. Root.	Reciprocal.	Circum.	Area.
309 95,481 29,503,629 17,5784 6,7606 0,03236246 970,75 74,990.6 3010 95,791,000 17,6685 6,7872 0,03225836 973,87 75,476.7 311 96,721 30,080,231 17,6852 6,7752 0,03215434 977,04 75,964.5 312 97,344 30,371,328 17,6855 6,7862 0,03216434 977,04 75,964.5 313 97,996 30,664.297 17,6918 6,7897 0,03194888 983,32 76,944.8 314 99,856 30,951,44 17,7200 6,799 0,0318457 398,32 77,437.3 315 99,225 31,255,875 17,7482 6,8041 0,03174603 999,00 77,931.1 316 99,856 31,554,496 17,7744 6,813 0,03144603 999,00 77,931.1 317 100,489 31,855,013 17,8045 6,8185 0,03134574 995,88 78,922,3 319 101,761 32,461,759 17,8066 6,8256 0,03134574 995,88 78,922,3 320 102,400 32,768,000 17,8885 6,8399 0,03125000 1,005,31 30,424.7 322 103,684 33,386,248 17,9444 6,8541 0,03105590 1,011,59 34,432,232 104,879 33,698,267 17,9722 6,8612 0,030368420 1,011,59 34,432,232 324 104,976 34,012,224 18,0000 6,8683 0,03086420 1,017,88 80,982,27 106,525 34,323,125 18,0278 6,853 0,03086420 1,017,88 82,447.9 32,27 106,59 34,645,976 18,055 6,8824 0,03036780 1,004,73 81,938,82 328 107,584 35,287,552 18,1108 6,8964 0,03038780 1,024,16 83,468,9 322 108,404 35,287,552 18,1108 6,8964 0,03038780 1,030,44 84,496,2 33,914,244 33,946,911 18,1834 6,904 0,0303931 1,030,44 84,496,2 33,914,18 34,946 34	308	94,864	29,218,112	17.5499	6.7533	.003246753	967.61	74,506.0
311 96,721 30,080,231 17,6855 6,7762 .008215484 977,04 75,964,5 312 97,344 30,371,329 17,6635 6,7892 .003194888 983,32 76,944,6 313 97,996 30,664,297 17,6916 6,7699 .003194888 983,32 76,944,6 316 99,255 31,255,875 17,7422 6,7699 .00319488 989,60 77,931,1 316 99,265 31,554,496 17,7764 6,8185 .00314657 992,74 78,426.7 318 101,761 32,617,432 17,8806 6,8256 .003144654 999,03 79,422.6 320 102,400 32,768,000 17,8895 6,8399 .003125000 1,006,31 80,422.7 321 103,641 33,766,161 17,9125 6,8470 .003152500 1,001,53 81,433.2 323 104,376 34,012,224 18,000 6,8682 .003068420 1,017,88 82,447.9 325 105,625 <td< td=""><td>309</td><td></td><td>29,503,629</td><td>17.5784</td><td>6.7606</td><td></td><td></td><td>74,990.6</td></td<>	309		29,503,629	17.5784	6.7606			74,990.6
312 97,344 30,371,328 17,6695 6,7824 .003205128 980,18 76,454,63 314 98,596 30,959,144 17,790 6,7969 .003184713 986,46 77,432,1 316 99,255 31,255,875 17,7482 6,8041 .003174603 989,60 77,931,1 317 100,489 31,855,013 17,8046 6,8185 .003164574 995,88 78,922,8 318 101,124 31,517,432 17,8366 6,8256 .003134796 1,002,17 79,922,3 319 101,761 32,461,759 17,8606 6,8329 .003134796 1,002,17 79,922,3 320 102,400 32,768,000 17,9444 6,8470 .00315265 1,008,45 80,928,2 321 103,684 33,368,287 17,9424 6,8612 .003095975 1,014,73 81,932,8 322 106,864 34,328,125 18,000 6,8632 .00306420 1,017,78 82,457 325 106,929	310		29,791,000	17.6068	6.7679	.003225806	973.89	75,476.7
313 97,989 30,644,287 17,6918 6,7897 .003194888 983,32 76,944,6 314 98,956 30,989,144 17,7200 6,7699 .003194813 986,6 77,931,1 316 99,255 31,255,875 17,7422 6,8041 .003174603 989,60 77,931,1 317 100,499 31,855,013 17,8046 6,8185 .003144654 999,03 79,422,6 318 101,761 32,461,759 17,8806 6,8256 .003144654 999,03 79,422,6 320 102,400 32,768,000 17,8856 6,8399 .003125000 1,006,31 80,422,7 321 103,041 33,076,161 17,9126 6,8470 .003152595 1,008,45 80,222,2 322 104,976 34,012,224 18,000 6,8682 .00306909 1,011,59 81,433,2 325 106,625 34,386,248 17,912 6,8612 .003096795 1,014,73 81,936 252 106,525 <t< td=""><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></t<>								
314 98,596 30,959,144 17,7200 6,7969 .003184713 986,46 77,437.1 316 99,225 31,255,875 17,7764 6,8113 .003164557 992,74 78,425.7 317 100,499 31,855,013 17,8045 6,8185 .003145577 992,74 78,422.7 318 101,124 32,157,432 17,8366 6,8256 .003144654 999,03 79,422.8 319 101,761 32,461,759 17,8866 6,8328 .003134786 1,002,217 79,922.3 321 103,041 33,076,161 17,9165 6,8470 .003115265 1,001,159 84,328,122 322 103,684 33,366,287 17,944 6,8512 .003095975 1,014,73 81,993,22 324 104,976 34,012,224 18,000 6,8612 .003096795 1,011,58 81,329,32 326 106,276 34,651,783 18,055,6 6,8753 .003067485 1,024,16 8,4862 331 109,561 <td></td> <td>97,344</td> <td>30,371,328</td> <td></td> <td></td> <td></td> <td></td> <td>76,453.8</td>		97,344	30,371,328					76,453.8
317 100,489 31,855,013 17.8045 6.8185 .003154574 995.88 78,922.8 318 101,124 32,157,432 17.8326 6.8256 .003144654 999.03 79,422.6 320 102,400 32,768,000 17.8855 6.8399 .003125000 1,008.31 80,422.7 321 103,644 33,386,248 17.9144 6.8412 .003059575 1,014.73 81,433.2 322 104,976 34,012,224 18.0000 6.8683 .003086420 1,017.58 82,447.9 325 105,625 34,628,125 18.0578 6.8753 .003076923 1,021.02 82,957.6 326 106,766 34,645,976 18.0555 6.8894 .003048780 1,021.06 83,468.9 328 107,584 35,287,552 18.1184 6.9044 .003039514 1,023.04 84,4562.2 330 108,900 35,337,000 18.1659 6.914 .003030314 1,030.34 84,4562.2 332 102,524		97,969		17.0918		.003194888	983.32	77 427 1
317 100,489 31,855,013 17.8045 6.8185 .003154574 995.88 78,922.8 318 101,124 32,157,432 17.8326 6.8256 .003144654 999.03 79,422.6 320 102,400 32,768,000 17.8855 6.8399 .003125000 1,008.31 80,422.7 321 103,644 33,386,248 17.9144 6.8412 .003059575 1,014.73 81,433.2 322 104,976 34,012,224 18.0000 6.8683 .003086420 1,017.58 82,447.9 325 105,625 34,628,125 18.0578 6.8753 .003076923 1,021.02 82,957.6 326 106,766 34,645,976 18.0555 6.8894 .003048780 1,021.06 83,468.9 328 107,584 35,287,552 18.1184 6.9044 .003039514 1,023.04 84,4562.2 330 108,900 35,337,000 18.1659 6.914 .003030314 1,030.34 84,4562.2 332 102,524				17.7200			980.40	77 931 1
317 100,489 31,855,013 17.8045 6.8185 .003154574 995.88 78,922.8 318 101,124 32,157,432 17.8326 6.8256 .003144654 999.03 79,422.6 320 102,400 32,768,000 17.8855 6.8399 .003125000 1,008.31 80,422.7 321 103,644 33,386,248 17.9144 6.8412 .003059575 1,014.73 81,433.2 322 104,976 34,012,224 18.0000 6.8683 .003086420 1,017.58 82,447.9 325 105,625 34,628,125 18.0578 6.8753 .003076923 1,021.02 82,957.6 326 106,766 34,645,976 18.0555 6.8894 .003048780 1,021.06 83,468.9 328 107,584 35,287,552 18.1184 6.9044 .003039514 1,023.04 84,4562.2 330 108,900 35,337,000 18.1659 6.914 .003030314 1,030.34 84,4562.2 332 102,524				17.7764			992.74	78,426.7
318 101, 124 32, 157, 432 17, 8326 6,8328 003134796 1,002,17 79, 422,6 320 102,400 32, 768,000 17, 8885 6,8328 003125000 1,005,31 80,424,7 321 103,684 33,386,248 17, 9446 6,8541 0.03115505 1,008,43 80,928,2 322 104,329 33,698,267 17, 9722 6,8612 0.03095975 1,011,73 81,393,8 324 104,976 34,012,224 18,0000 6,8683 0.03086420 1,017,88 82,447.9 325 105,625 34,828,125 18,0556 6,8824 0.03095785 1,021,02 82,957.6 326 106,276 34,665,783 18,1818 6,894 0.03048780 1,022,18 83,483,23 329 108,241 35,611,289 18,1834 6,994 0.03030303 1,033,58 85,012,2 331 109,561 36,594,591 18,1834 6,9174 0.03030303 1,046,11 1,039,78 86,694.9				17.8045			995.88	78,923.8
320 102,400 32,768,000 17,8885 6,8390 ,003125000 1,008,43 80,424,23 321 103,684 33,366,248 17,9122 6,8470 ,003115265 1,011,59 81,433,23 322 104,329 33,688,267 17,9722 6,8683 ,003095975 1,011,59 81,433,23 325 105,625 34,281,25 18,0078 6,8824 ,003095975 1,011,59 81,433,28 326 106,276 34,665,976 18,0555 6,8824 ,003086420 1,021,02 82,957,62 327 106,929 34,965,783 18,0831 6,8894 ,00308104 1,027,30 83,4828,12 328 107,584 35,287,552 18,1108 6,8964 ,003039303 1,030,44 4,496,2 330 108,900 35,337,000 18,1659 6,914 ,003039303 1,030,34 4,496,2 331 109,561 36,594,691 18,2433 6,931 ,00303003 1,040,29 87,615,8 332 110,							999.03	79,422.6
321 103,041 33,076,161 17.9165 6.8470 .003115265 1,008.45 80,9282. 322 104,369 33,386,248 17.9424 6.8541 .003105590 1,011.59 81,438.2 324 104,976 34,012.224 18.0000 6.8683 .0030676923 1,017.88 82,447.9 325 105,625 34,646,976 18.0555 6.8894 .003057845 1,021.02 82,957.6 326 106,7584 35,287,552 18.1108 6.8944 .003057845 1,027.30 83,991.8 329 108,241 35,611,299 18.1834 6.9044 .003039314 1,033.58 85,502.8 331 109,561 36,264,691 18.1659 6.9104 .003030303 1,030.74 86,569.7 333 110,224 36,594,368 18.2209 6,2244 .003012048 1,043.01 86,569.7 335 112,225 37,595,375 18.3036 6,932 .002994012 1,040.29 87,615.8 336 112		101,761						
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323 104,329 33,698,267 17.9722 6.8683 003086420 1,017.88 82,447.9 325 106,625 34,628,125 18.0020 6.8683 003086420 1,017.88 82,447.9 326 106,276 34,645,976 18.0555 6.8824 .003058104 1,021.02 82,957.6 327 106,929 34,965,783 18.0831 6.8894 .003048780 1,030.44 84,496.2 329 108,241 35,611,289 18.1384 6.9034 .003039314 1,033.58 85,012.2 330 108,900 35,937.000 18.1659 6.9104 .003030303 1,039.67 86,594.93 331 10,889 36,594,691 18.1834 6.9174 .00303030 1,046.15 87,092.0 333 110,224 36,594,388 18.2209 6.9244 .03003003 1,046.15 87,092.0 334 115,569 37,595,375 18.3030 6.9451 .00299755 1,052.24 88,141.33 337 113,669<	321	103,041	33,076,161	17.9165				80,928.2
324 104,66 34,012,224 18,0000 6.8683 .003086420 1,017,38 82,957.6 326 106,626 34,628,195 18,0278 6.8753 .003076923 1,021,02 82,957.6 327 106,929 34,965,783 18,0631 6.8894 .003048780 1,027.30 83,981.8 328 107,584 35,287,552 18,1108 6.8964 .003048780 1,030.44 84,496.2 330 108,900 35,937,000 18,1659 6.9104 .003039314 1,033.78 85,529.8 331 109,561 36,264,691 18,1834 6.9144 .003021148 1,030.73 85,529.8 332 110,224 36,594,368 18,2299 6,93424 .003021148 1,043.01 86,569.7 333 110,896 37,333,056 18,2336 6,9313 .00309033 1,046.15 87,022.0 334 112,226 37,593,756 18,3303 6,9527 .00294012 1,049.29 87,615.8 335 112,29		100,004						81 030 9
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226 106,276 34,645,976 18,655 6,8824 .003067485 1,021,16 83,486,976 327 106,929 34,965,783 18,0831 6,8894 .003048780 1,027,30 83,981.8 328 107,584 35,287,552 18,1184 6,8964 .003048780 1,030,44 84,496.2 330 108,900 35,937,000 18,1659 6,9104 .003039314 1,033,58 85,012.2 331 109,561 36,264,691 18,1834 6,9174 .003021148 1,033,78 66,6949.1 333 110,899 36,594,368 18,2299 6,9244 .006012048 1,043,01 86,569,7 333 110,896 37,259,704 18,2757 6,9382 .002994012 1,042,29 87,615,8 336 112,296 37,933,056 18,3303 6,9451 .002976190 1,055,58 88,668,3 337 115,669 38,272,753 18,3491 6,9592 .002967359 1,068,14 9,727,0 338 114	325		34,328,125					82,957.6
327 106,929 34,965,783 18.0831 6.8964 .003058104 1,027,30 83,961,84 4.96.2 328 107,584 35,297,552 18.1108 6.8964 .00303914 1,030.48 84,496.2 330 108,900 35,937,000 18.1659 6.9104 .00303933 1,036.73 85,529.8 331 109,561 36,294,691 18.1934 6.9174 .003021148 1,043.01 86,569.7 332 110,224 36,594,368 18.2209 6.9244 .003021048 1,043.01 86,569.7 334 111,556 37,559,704 18.2757 6.9382 .092994012 1,042.29 87,615.8 335 112,896 37,933,056 18.3303 6.9521 .002976190 1,055.58 88,668.3 337 113,569 33,934,000 18.4391 6.9727 .002949553 1,061.66 89,727.0 339 114,921 38,958,129 18.4120 6.9795 .002949553 1,061.66 89,727.0 34	326	106,276		18.0555				83,468.9
329 108,241 35,611,289 18,1384 6,904 .003039514 1,033,58 85,512,8 330 109,561 36,264,691 18,1659 6,9104 .003029148 1,036,73 85,529,8 331 109,561 36,264,691 18,1934 6,9174 .003021148 1,038,37 86,049,0 332 110,224 36,594,368 18,2299 6,9244 .003021048 1,043,01 86,569,7 334 111,556 37,259,704 18,2757 6,9382 .002994012 1,040,29 87,615,8 336 112,896 37,933,056 18,3303 6,9451 .002976190 1,055,68 88,688,3 337 113,569 38,272,753 18,3576 6,9589 .002956359 1,055,82 38,141,33 339 114,244 38,614,472 18,3818 6,9589 .002956359 1,061,86 89,727,0 340 115,600 39,361,821 18,4391 6,9795 .00294176 1,068,14 9,722,34 341 116,9	327	106,929	34,965,783	18.0831			1,027.30	83,981.8
330 106,900 35,937,000 18,1659 6,9104 003030303 1,036,73 85,529,8 86,049.0 331 109,561 36,294,691 18,1934 6,9174 003021148 1,039,87 86,049.0 332 110,224 36,594,368 18,2209 6,9244 003012048 1,043,01 86,569.7 333 111,556 37,595,775 18,2303 6,9322 002994012 1,049,29 87,615.8 336 112,296 37,595,375 18,3030 6,9521 002985075 1,055,58 88,668.3 337 113,569 38,272,753 18,3576 6,9521 002985075 1,055,58 88,668.3 338 114,924 38,614,472 1,8348 6,9589 002967859 1,056,128 89,196.8 340 115,600 39,304,000 18,4391 6,9797 002941176 1,068,14 90,772.6 341 116,294 40,001,688 18,4932 6,9964 002932551 1,071,28 91,368,31 342 <td>328</td> <td>107,584</td> <td>35,287,552</td> <td></td> <td></td> <td></td> <td>1,030.44</td> <td>84,496.2</td>	328	107,584	35,287,552				1,030.44	84,496.2
331 106,561 36,594,691 18,1934 6,9174 003021148 1,039,67 86,694,068 86,694,068 110,224 36,594,368 18,209 6,9244 008012048 1,043,01 86,569,7 86,694,7 333 110,889 36,926,037 18,2483 6,9313 003003003 1,046,15 87,092,0 37,933,056 18,3303 6,9451 002980751 1,052,43 88,141.33 336 112,896 37,933,056 18,3303 6,9451 002976190 1,055,88 88,668.31 337 115,569 38,272,753 18,3576 6,9589 0029567559 1,055,88 88,668.31 339 114,921 38,958,219 18,4120 6,9797 002941955 1,068,14 90,727,06 341 116,281 39,651,821 18,4891 6,9795 002925377 1,071,28 91,326,83 342 116,964 40,001,688 88,4932 6,9932 0029259851 1,077,57 92,401,31 344 118,366 40,707,584 18,5742 7,0036 0029299877 1,080,71 92,940.88 <td></td> <td>108,241</td> <td>35,611,289</td> <td></td> <td></td> <td></td> <td></td> <td></td>		108,241	35,611,289					
332 110,224 36,594,368 18,2299 6,9244 006012048 1,043,01 86,569,77 333 110,889 36,926,037 18,2483 6,9313 003003003 1,046,15 87,092,07 334 111,556 37,595,375 18,3030 6,9451 .002985075 1,052,43 88,141,33 336 112,896 37,933,566 18,3303 6,9521 .002975599 1,055,58 88,668,33 337 113,569 38,272,753 18,33676 6,9589 .002967859 1,055,58 88,668,37 339 114,921 38,958,219 18,4120 6,9727 .002949853 1,061,66 89,727,06 340 115,600 39,304,000 18,4391 6,9795 .00294176 1,068,14 90,792,03 341 116,264 40,001,688 18,4932 6,9932 .002923977 ,1074,42 91,863,31 342 116,964 40,001,688 18,4932 6,9932 .002923977 ,1074,42 91,863,31 345 <								
333 110,889 36,926,037 18,2483 6,9382 .002994012 1,046,15 87,092.0 334 111,556 37,259,704 18,2757 6,9382 .002994012 1,049,29 87,615.8 335 112,225 37,595,375 18,3030 6,9451 .002985075 1,052,43 88,141.3 336 112,896 37,933,056 18,3303 6,9521 .002967359 1,055,72 89,196.8 338 114,244 38,614,472 18,3484 6,9589 .002949853 1,065,00 90,258,73 340 115,600 39,304,000 18,4391 6,9795 .002941176 1,066,14 90,792,03 341 116,964 40,01,688 18,4932 6,9932 .0022923977 1,074,42 91,368,33 345 119,065 41,063,625 18,5742 7,0068 .002290577 1,080,71 92,401.8 345 119,016 41,221,736 18,6011 7,0231 .00289677 1,088,99 94,024.73 346 1								
335 112,225 37,595,375 18,3030 6,9451 002985075 1,052,43 88,141.33 336 112,896 37,933,056 18,3303 6,9521 0029676190 1,055,58 88,668.33 337 113,569 38,272,753 18,3576 6,9521 002967359 1,055,58 88,668.33 338 114,244 38,614,472 18,3848 6,9658 002958800 1,061,06 89,727.02 340 115,600 39,304,000 18,4891 6,9727 002941176 1,068,14 90,792.03 341 116,281 39,561,821 18,4620 6,9864 002923571 1,071,28 91,326.8 342 116,964 40,001,688 18,4932 6,9964 002923577 1,074,42 91,863,31 343 117,649 40,835,607 18,5023 7,0000 002915452 10,77,57 92,401,31 346 119,716 41,221,736 18,6011 7,0027 002890551 1,083.27 92,401,31 348 121,								87,092.02
336 112,896 37,933,056 18,3303 6,9521 002976190 1,055,72 88,668,32 337 113,569 38,272,753 18,3376 6,9589 002967359 1,058,72 89,196,8 338 114,244 38,614,472 18,3848 6,9658 002958580 1,061.06 89,727,03 340 115,600 39,304,000 18,4391 6,9795 002941176 1,068,14 90,792,0 341 116,864 40,001,688 18,4392 6,9932 002923977 1,074,42 91,368,3 342 116,964 40,001,688 18,5492 7,0008 .002206977 1,074,27 91,368,3 343 117,649 40,358,607 18,5203 7,0000 .00293957 1,076,57 92,401,31 346 119,025 41,663,625 18,5742 7,0036 .002898571 1,080,71 92,940,24,73 347 12,049 41,781,923 18,6279 7,0271 .002881841 1,990,13 96,622 350 122,50	334							87,615.88
337 113,569 38,272,753 18,3576 6,958 0,02967359 1,058,72 89,196,88 7,770 338 114,244 38,614,472 18,3348 6,958 0,02958580 1,061,86 89,727,03 340 115,600 39,304,000 18,4321 6,9795 0,02941176 1,068,14 90,792,03 341 116,281 39,651,821 18,4662 6,9864 0,0232351 1,071,28 91,326,88 342 116,964 40,001,688 18,4932 6,9932 0,022923977 1,074,42 91,863,31 344 118,336 40,707,584 18,5742 7,0006 0,02906977 1,080,71 92,940,13 345 119,025 41,063,625 18,5742 7,0136 0,02898551 1,083,55 348,22,23 346 119,716 41,781,223 18,6011 7,0203 0,02898551 1,080,71 92,940,38 347 120,409 41,781,223 18,6548 7,037 0,02893630 1,093,27 95,662,23	335	112,225						
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339 114,921 38,958,219 18,4120 6,9725 002949853 1,065,00 90,258,7 340 115,600 39,304,000 18,4391 6,9795 002941176 1,068,14 90,792,02 341 116,281 40,001,688 18,4932 6,9932 002923977 1,074,42 91,863,31 342 116,949 40,853,607 18,5203 7,0000 002906977 1,087,17 192,940,83 344 118,336 40,707,584 18,5742 7,0036 002906977 1,080,71 92,940,83 345 119,025 41,063,625 18,5742 7,0136 002898571 1,083,55 94,224,73 346 119,716 41,421,736 18,6011 7,0203 002890173 1,080,99 94,024,73 347 120,409 41,781,923 18,6548 7,0338 002873563 1,090,13 94,569,01 350 122,801 42,508,649 18,7687 7,0473 002857353 1,095,56 96,211,28 351 123,			38 614 472					89 797 03
340 115,600 39,304,000 18,4391 6,9795 002941176 1,068,14 90,792,02 341 116,281 39,651,821 18,4662 6,9864 002932551 1,071,28 91,326,88 342 116,964 40,001,688 18,4932 6,9932 002925977 1,074,22 91,863,31 343 117,649 40,353,607 18,5203 7,0006 0029269677 1,080,71 92,401,38 345 119,025 41,033,625 18,5742 7,0136 002896551 1,088,79 94,024,73 346 119,716 41,221,736 18,6011 7,0203 002898551 1,086,99 94,024,73 347 120,409 41,781,923 18,6279 7,0271 002881844 1,090,13 94,669,01 349 121,801 42,508,549 18,6815 7,0406 002865330 1,096,42 95,662,28 350 122,500 42,875,000 18,7083 7,0474 002849003 1,102,70 96,761.8 351 123,								
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343 117,649 40,353,607 18,5203 7,0008 002915452 1,077,57 92,401.33 344 118,336 40,707,584 18,5472 7,0068 002906977 1,080,71 92,940.88 345 119,716 41,421,736 18,6011 7,0203 002898551 1,083.85 93,482.02 346 119,716 41,781,923 18,6079 7,0203 00289173 1,086.99 94,024.73 348 121,104 42,144,192 18,6548 7,0338 002873563 1,093.27 95,114.88 350 122,500 42,875,000 18,7683 7,0406 002865330 1,096.42 95,662.28 351 123,201 43,243,551 18,7507 7,0540 002849003 1,102.70 96,761.84 354 125,316 44,361,864 18,8149 7,0740 002824989 1,115.84 97,867.68 355 126,025 44,738,875 18,844 7,0870 00284089 1,115.27 98,979.80 355 126,025						.002932551		91,326.88
344 118,336 40,707,584 18,5742 7.0068 .002906977 1,080,71 92,940,88 345 119,025 41,063,625 18,5742 7.0136 .002898551 1,083,85 93,482,02 346 119,716 41,421,736 18,6011 7.0203 .002891673 1,086,99 94,024,73 347 120,409 41,781,923 18,6679 7.0271 .002881844 1,090,13 94,569,01 348 121,104 42,144,192 18,6548 7.0338 .002873563 1,093,27 95,114.8 359 122,500 42,508,649 18,6815 7.0473 .002857134 1,099,56 96,211.28 351 123,201 43,243,551 18,7657 7.0574 .002849090 1,105,84 97,867.68 352 123,904 43,864,977 18,7883 7.0674 .002832861 1,108.98 97,867.68 354 125,316 44,361,864 18,8144 7.0807 .002832861 1,115.27 98,97.80 355 <		116,964	40,001,688					
346 119,025 41,063,625 18,5742 7,0136 ,002896551 1,083,85 93,482,02 346 119,716 41,21,736 18,6011 7,0203 ,002890178 1,086,99 94,024,73 347 120,409 41,781,923 18,6279 7,0271 ,002881844 1,090,13 94,569,01 348 121,104 42,144,192 18,6615 7,0471 ,002865330 1,098,22 95,114,88 350 122,500 42,875,000 18,7683 7,0473 ,002857143 1,099,56 96,211,28 351 123,201 43,243,551 18,7350 7,0540 ,002849009 1,102,70 96,761,84 352 123,904 43,614,208 18,7617 7,0607 ,002849009 1,102,84 97,313,97 353 124,609 43,986,977 18,8849 7,0740 ,002824859 1,112,12 98,422,96 356 126,025 44,738,875 18,8414 7,0807 ,002808989 1,118,41 98,939,28 357		117,049	40,353,607	18.5203				92,401.31
346 119,716 41,421,736 18,6011 7.0233 002890173 1,086,99 94,569.01 347 120,409 41,781,923 18,6279 7.0271 002881844 1,090.13 94,569.01 348 121,104 42,144,192 18,6548 7.0338 002873563 1,098,27 95,114.86 350 122,500 42,508,649 18,6815 7.0476 002857333 1,098,62 95,662.21.28 351 123,201 43,243,551 18,7637 7.0570 002849903 1,105,84 96,711.8 352 129,904 43,614,208 18,7617 7.0607 002849909 1,105,84 97,831.97 354 125,316 44,361,864 18,8149 7.0740 002849899 1,112,12 98,422.96 355 126,736 45,118,016 18,8680 7.0874 002809899 1,118,12 98,588.22 356 126,736 45,118,016 18,8680 7.0873 002280989 1,118,41 99,588.23 357 12		119 025	41 063 625	18 5742	7.0006			92,540.00
347 120,409 41,781,923 18,6279 7,0271 002881844 1,090,13 94,569,01 348 121,104 42,144,192 18,6548 7,0338 002873563 1,099,327 95,114,86 319 121,801 42,508,549 18,8815 7,0473 002856330 1,099,56 96,622,23 350 122,500 42,875,000 18,7083 7,0473 002857143 1,099,56 96,761,84 351 123,201 43,243,551 18,7350 7,0540 002849009 1,102,70 96,761,84 352 123,904 43,614,208 18,7617 7,0607 002849009 1,108,84 97,313,97 353 126,699 43,986,977 18,7883 7,0474 002824859 1,112,12 98,729,89 356 126,025 44,738,875 18,8414 7,0807 002816901 1,115,27 98,979,89 357 127,449 45,199,293 18,8943 7,040 002971200 1,121,55 100,082 358 128,16								
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350 122,500 42,875,000 18,7083 7,047a 002857143 1,099.56 96,211.28 351 123,201 43,243,551 18,7350 7,0540 002849003 1,102.70 96,761.84 352 123,904 43,814,208 18,7617 7,0607 002849009 1,105.84 97,831.87 353 124,609 43,986,977 18,7883 7,0674 002824859 1,115.28 97,867.68 354 125,316 44,361,864 18,8149 7,0740 002824859 1,112.12 98,422.96 355 126,025 44,738,875 18,8414 7,0807 002816901 1,115.27 98,979.80 356 126,736 45,118,016 18,8680 7,067 0022908989 1,118.41 99,538.22 357 127,449 45,199,293 18,9473 7,1072 002793266 1,124.69 100,659.7 359 128,881 46,268,279 18,9473 7,1072 002782566 1,127.83 101,787.60 361 130						.002873563		95,114.86
352 123,904 43,614,208 18.7617 7.0607 .002840909 1,105.84 97,313.97 353 124,609 43,986,977 18.7883 7.0674 .002832861 1,112.12 98,422.96 354 125,316 44,331,864 18.8149 7.0740 .002832861 1,112.12 98,422.96 355 126,736 45,118,016 18.8684 7.0807 .002809898 1,112.12 98,979.80 357 127,449 45,199.293 18.8944 7.0940 .002801120 1,121.56 100.098.21 358 128,164 45,882.712 18.9209 7.1006 .002793296 1,124.69 100,659.77 360 129,600 46,656,000 18.9737 7.1133 .002777778 1,130.97 101,787.60 361 130,321 47,437.928 19.0026 7.1204 .002770383 1,141.04 103,491.13 363 131,769 47,832,147 19.0526 7.1355 .002742431 1,140.40 103,491.13 366				18.6815				95,662.28
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353 124,609 43,986,977 18,7883 7.0674 002832861 1,108,98 97,867.86 354 125,316 44,361,864 18,8149 7.0740 002824859 1,112,12 84,22,96 356 126,025 44,738,875 18,8414 7.0807 .002816901 1,115,27 98,979.80 357 127,449 45,199,293 18,8844 7.0940 .002801129 1,121,55 100,098.21 358 128,164 45,882,712 18,9209 7.1006 .002783516 1,127,83 100,659,77 360 129,600 46,656,000 18,9737 7.1138 .002777778 1,130,97 101,787.60 361 130,321 47,045,881 19,0263 7.1204 .0027762431 1,137.26 102,933.87 363 131,769 47,832,147 19,078 7,1304 .002762431 1,145.40 103,491.13 365 133,255 48,627,125 19,1050 7,1466 .002739261 1,146.82 104,634.67 366			43 614 208					97 313 97
354 125,316 44,361,864 18,8149 7,0740 .002824859 1,112,12 38,422,98 356 126,025 44,738,875 18,8414 7,0807 .002816901 1,115,27 98,979.80 356 126,736 45,118,016 18,8680 7,0873 .002808989 1,118,41 99,538.22 357 127,449 45,199,293 18,8944 7,0940 .002801120 1,121,55 100,098.21 358 128,164 45,882,712 18,9209 7,1006 .002793296 1,124,69 100,069.77 360 129,600 46,656,000 18,9737 7,1133 .002777778 1,130,19 101,787.60 361 130,321 47,045,881 19,0000 7,1204 .00277038 1,134,11 102,253.87 362 131,044 47,437,928 19,0526 7,1355 .0027764231 1,140.40 103,491.13 363 131,769 47,832,147 19,0526 7,1365 .00273926 1,146.58 104,632.67 366	353							
356 126,736 45,118,016 18,8680 7,0873 .002908989 1,118,41 99,538,22 357 127,449 45,199,293 18,8944 7,0940 .002801120 1,121,55 100,098,21 358 128,164 45,882,712 18,9209 7,1006 .002793296 1,124,69 100,659,77 359 129,600 46,656,000 18,9737 7,1172 .002785515 1,127,83 101,222,90 361 130,321 47,045,881 19,0000 7,1204 .002770083 1,134,41 102,353,87 362 131,044 47,437,928 19,0526 7,1269 .002762431 1,137,26 102,921,72 363 131,769 47,832,147 19,0526 7,1355 .002754821 1,140,40 103,491,13 366 133,225 48,627,125 19,1050 7,1466 .00273926 1,146,58 104,684,67 366 133,956 49,027,896 19,1811 7,1531 .00273926 1,146,58 105,208,80 367	354	125,316	44,361,864	18.8149	7.0740		1,112.12	98,422.96
357 127,449 45,499,293 18,8944 7,0940 002201120 1,121,55 100,098,21 358 128,164 45,882,712 18,9209 7,1006 002793296 1,124,69 100,659,77 359 128,881 46,268,279 18,9473 7,1072 002785515 1,127,83 101,222,90 360 129,600 46,656,000 18,9737 7,1133 002777078 1,139,17 101,285,87 361 130,321 47,045,881 19,0000 7,1204 00277038 1,134,11 102,358,87 362 131,044 47,437,928 19,0526 7,1355 0027764821 1,140,40 103,491.13 363 132,496 48,228,544 19,0788 7,1400 002747253 1,146,54 104,682.1 366 133,225 48,627,125 19,1050 7,1466 002739726 1,146,58 104,634.6* 367 134,689 49,430,863 19,1572 7,1596 002724796 1,152,96 105,784.49 369				18.8414				
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359 128,881 46,268,279 18.9473 7.1072 .002785515 1,127.83 101,222.90 360 129,600 46,656,000 18.9737 7.1138 .002777778 1,130.97 10.787.60 361 130,321 47,045,881 19.0000 7.1204 .002770083 1,134.11 102,353.87 362 131,769 47,437,928 19.0526 7.1269 .002754821 1,140.40 103,491.13 364 132,496 48,228,544 19.0788 7.1400 .002734726 1,146.54 104,682.12 366 133,956 49.027,896 19.1311 7.1531 .002732264 1,149.82 105,208.80 367 134,689 49.430,863 19.1572 7.1566 .002724796 1,152.96 105,784.9 368 135,424 49.836,032 19.1833 7.1661 .002717391 1,156.11 106,381.76 369 136,161 50,243,409 19.2094 7.1726 .002710327 1,159.25 106,940.80			45,499,295					
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362 131,044 47,437,928 19,0263 7,1269 002762431 1,137,26 102,921,73 363 131,769 47,832,147 19,0526 7,1335 .002754821 1,140,40 103,491,13 364 132,496 48,228,544 19,0788 7,1400 .002747253 1,145,54 104,062,12 366 133,225 48,627,125 19,1050 7,1466 .00273926 1,146,68 104,634.67 367 134,689 49,430,863 19,1572 7,1596 .002724796 1,152,96 105,784.49 368 135,424 49,830,322 19,1831 7,1661 .0027124796 1,152,96 105,784.49 369 136,161 50,243,409 19,2094 7,7726 .00271027 1,156,21 106,840.70	361	130,321	47,045,881	19.0000	7.1204	.002770083	1,134.11	102,353.87
364 132.496 48.228.544 19.0788 7.1400 .002747253 1,143.54 104,062.16 365 133.225 48.627.125 19.1050 7.1466 .00273926 1,146.68 104,634.67 366 133.956 49.027.896 19.1311 7.1531 .0027332240 1,149.82 105.208.80 367 134.689 49.430.863 19.1572 7.1596 .002724796 1,152.96 105,784.9 368 135.424 49.836,032 19.1833 7.1661 .002717391 1,156.21 106,361.76 369 136,161 50,243,409 19.2094 7.1726 .002710027 1,159.25 106,940.80								102,921.72
.365 133,225 48,627,125 19,1050 7,1466 002739726 1,146,88 104,834,67 366 133,956 49,027,896 19,1311 7,1531 .002732240 1,149,82 105,208,80 367 134,689 49,430,863 19,1572 7,1596 .002724796 1,152,96 105,784,49 368 135,424 49,836,032 19,1833 7,1661 .002717391 1,156,21 106,961,76 369 136,161 50,243,409 19,2094 7,1726 .00271027 1,159,25 106,940,80								103,491.13
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	370	136,900					1,162.39	
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No.	Square.	Cube.	Sq. Root.	Cu. Root.	Reciprocal.	Circum.	Area.
871	137,641	51,064,811	19.2614	7.1855	.002695418	1,165.53	108,102.99
\$72 \$73	138,384	51,478,848	19.2873 19.3132	7.1920 7.1984	.002688172 .002680965	1,168.67	108,686.5
374	139,129 139,876	51,895,117 52,313,624	19.3391	7.2048	.002680965	1,171.81 1,174.96	109,271.6 109,858.3
375	140,625	52,734,375	19.3649	7.2112	.002666667	1,178.10	110,446.6
376	141,376	53,157,376	19.3907	7.2177	.002659574	1,181.24	111,036.4
377 378	142,129 142,884	53,582,633	19.4165 19.4422	7.2240 7.2304	.002652520	1,184.38 1,187.52	111,627.80 112,220.83
379	143,641	54,010,152 54,439,939	19.4679	7.2368	.002638521	1,190.66	112,220.8
380	144,400	54,872,000	19.4936	7.2432	.002631579	1,193.81	113,411.49
381	145,161	55,306,341	19.5192	7.2495	.002624672	1,196.95	114,009.18
382 383	145,924 146,689	55,742,968 56,181,887	19.5448 19.5704	7.2558 7.2622	.002617801 .002610966	1,200.09 1,203.23	114,608.44 115,209.27
384		56,623,104	19.5959	7.2685	.002604167	1,206.37	115,811.6
385	147,456 148,225	57,066,625	19.6214	7.2748	.002597403	1,209.51	116,415.64
386	148,996	57,512,456	19.6469	7.2811	.002590674	1,212.65	117,021.18
387 388	149,769 150,544	57,960,603 58,411,072	19.6723 19.6977	7.2874 7.2936	.002583979	1,215.80 1,218.94	117,628.30 118,236.96
389	151,321	58,863,869	19.7231	7.2999	.002570694	1.222.08	118,847.2
390	152,100	59,319,000	19.7484	7.3061	.002564103	1,225.22	119,459.00
391	152,881	59,776,471	19.7737	7.3124	.002557545	1,228.36	120,072.46
392 393	153,664	60,236,288 60,698,457	19.7990 19.8242	7.3186 7.3248	.002551020	1,231.50 1,234.65	120,687.42 121,303.96
394	154,449 155,236	61,162,984	19.8494	7.3310	.002538071	1,237.79	121,922.07
395	156,025	61,629,875	19.8746	7.3372	.002531646	1,240.93	122,541.75
396	156,816	62,099,136	19.8997	7.3434	.002525253	1,244.07	123,163.00
397 398	157,609 158,404	62,570,773 63,044,792	19.9249 19.9499	7.3496 7.3558	.002518892 .002512563	1,247.21 1,250.35	123,785.85 124,410.21
399	159,201	63,521,199	19.9750	7.3619	.002506266	1,253.50	125,036.17
400	160,000	64,000,000	20.0000	7.3681	.002500000	1,256.64	125,663.71
401	160,801	64,481,201	20.0250	7.3742	.002493766	1,259.78	126,292.81
402	161,604 162,409	64,964,808 65,450,827	20.0499 20.0749	7.3803 7.3864	.002487562 .002481390	1,262.92 1,266.06	126,923.48 127.555.73
404	163,216	65,939,264	20.0998	7.3925	.002475248	1,269.20	128,189.5
405	164,025	66,430,125	20.1246	7.3986	.002469136	1,272.35	128,824.93
406	164,836	66,923,416	20.1494 20.1742	7.4047 7.4108	.002463054 .002457002	1,275.49 1,278.63	129,461.89
407 408	165,649 166,464	67,419,143 67,917,312	20.1742	7.4169	.002457002	1,281.77	130,100.42 130,740.52
409	167,281	68,417,929	20.2237	7.4229	.002444988	1,284.91	131,382.19
410	168,100	68,921,000	20.2485	7.4290	.002439024	1,288.05	132,025.43
411 412	168,921 169,744	69,426,531 69,934,528	$20.2731 \ 20.2978$	7.4350 7.4410	.002433090	1,291.19 1,294.34	132,670.24 133,316.63
413	170,569	70,444,997	20.3224	7.4470	.002421308	1,297.48	133,964.58
414	171,396	70,957,944	20.3470	7.4530	.002415459	1,300.62	134,614.10
415	172,225	71,473,375	20.3715	7.4590	.002409639	1,303.76	135,265.20
416 417	173,056 173,889	71,991,296 72,511,713	20.3961 20.4206	7.4650 7.4710	.002406846	1,306.90 1,310.04	135,917.86 136,572.10
418	174,724	73,034,632	20.4450	7.4770	.002392344	1,313.19	137,227.91
419	175,561	73,560,059	20.4695	7.4829	.002386635	1,316.33	137,885.29
420	176,400	74,088,000	20.4939	7.4889	.002380952	1,319.47	138,544.24
421 422	177,241 178,084	74,618,461 75,151,448	20.5183 20.5426	7.4948 7.5007	.002375297	$1,322.61 \ 1,325.75$	139,204.76 139,866.85
423	178,929	75,686,967	20.5670	7.5067	.002364066	1,328.89	140,530.51
424	179,776	76,225,024	20.5913	7.5126	.002358491	1,332.04	141,195.74
425	180,625	76,765,625	20.6155	7.5185 7.5244	.002352941 $.002347418$		141,862.54
426 427	181,476 182,329	77,308,776 77,854,483	20.6398 20.6640	7.5302	.002347418		142,530.92 143,200.86
428	183,184	78,402,752	20.6882	7.5361	.002336449	1,344.60	143,872.38
429	184,041	78,953,589	20.7123	7.5420	.002331002	1.347.74	144,545,46
430	184,900 185,761	79,507,000 80,062,991	20.7364 20.7605	7.5478 7.5537	.002325581 $.002320186$	1,350.88 1,354.03	145,220.12 145,896.35
431 432	186,624	80,621,568	20.7846	7.5595	.002320160		146,574.15
433	187,489	81,182,737	20.8087	7.5654	.002309469		147,253.52
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52	squ	UARES, CUB	ES, SQUA	ARE AN	D CUBE R	00TS,	
No.	Square.	Cube.	Sq. Root.	Cu. Root.	Reciprocal.	Circum.	Area.
134	188,356	81,746,504	20.8327	7.5712	.002304147	1,363.45	147,934.46
135	189,225	82,312,875	20.8567	7.5770	.002298851	1,366.59	148,616.97
436	190,096	82,881,856	20.8806	7.5828	.002293578	1,369.73	149,301.05
137	190,969	83,453,453	20.9045	7.5886	.002288330	1,372.88	149,986.70
138	191,844	84,027,672	20.9284	7.5944	.002283105	1,376.02	150,673.93
139	192,721	84,604,519	20.9523	7.6001	.002277904	1,379.16	151,362.72
140	193,600	85,184,000	20.9762	7.6059	.002272727	1,382.30	152,053.08
141	194,481	85,766,121	21.0000	7.6117	.002267574	1,385.44	152,745.02
142	195,364	86,350,888	21.0238	7.6174	.002262443	1,388.58	153,438.53
143 144	196,249	86,938,307	21.0476	7.6232 7.6289	.002257336	1,391.73 1,394.87	154,133.60 154,830.25
145	197,136 198,025	87,528,384 88,121,125	21.0950	7.6346	.002247191	1,398.01	155,528.47
146	198,916	88,716,536	21.1187	7.6403	.002242152	1,401.15	156,228.26
147	199,809	89,314,623	21.1424	7.6460	.002237136	1,404.29	156,929.62
148	200,704	89,915,392	21.1660	7.6517	.002232143	1,407.43	157,632.55
149	201,601	90,518,849	21.1896	7.6574	.002227171	1.410.58	158,337.06
450	202,500	91,125,000	21.2132	7.6631	.002222222	1,413.72	159,043.13
451	203,401	91,733,851	21.2368	7.6688	.002217295	1,416.86	159,750.77
452	204,304	92,345,408	21.2603	7.6744	.002212389	1,420.00	160,459.99
453	205,209	92,959,677	21.2838	7.6801	.002207506	1,423.14	161,170.77
454	206,116	93,576,664	21.3073	7.6857	.002202643	1,426.28	161,883.13
455	207,025	94,196,375	21.3307	7.6914	.002197802	1,429.42	162,597.05
156	207,936	94,818,816	21.3542	7.6970	.002192982	1,432.57	163,312.55
457	208,849	95,443,993 96,071,912	21.3776	7.7026	.002188184	1,435.71	164,029.62
158	209,764	96,071,912	21.4009	7.7082	.002183406	1,438.85	164,748.26
159	210,681	96,702,579 97,336,000	21.4243	7.7188	.002178649	1,441.99	165,468.47
160	211,600	97,336,000	21.4476	7.7194	.002173913	1,445.13	166,190.25
461 460	212,521	97,972,181	21.4709 21.4942	7.7250 7.7306	.002169197	1,448.27 1,451.42	166,913.60
462 463	213,444 214,369	98,611,128 99,252,847	21.5174	7.7362	.002159827	1,454.56	167,638.53 168,365.02
164	215,296	99,897,344	21.5407	7.7418	.002155172	1,457.70	169,093.08
465	216,225	100,544,625	21.5639	7.7473	.002150538	1.460.84	169,822.72
166	217,156	101,194,696	21.5870	7.7529	.002145923	1.463.98	170,553.92
167	218,089	101,847,563	21.6102	7.7584	.002141328	1,467.12	171,286.70
168	219,024	102,503,232	21.6333	7.7639	.002136752	1,470.27	172,021.05
469	219,961	103,161,709	21.6564	7.7695	.002132196	1,473.41	172,756.97
470	220,900	103,823,000	21.6795	7.7750 7.7805	.002127660	1,476.55	173,494.45
171	221,841	104,487,111	21.7025	7.7805	.002123142	1,479.69	174,233.51
472	222,784	105,154,048	21.7256	7.7860	.002118644	1,482.83	174,974.14
473	223,729	105,823,817	21.7486	7.7915 7.7970	.002114165	1,485.97	175,716.35
174	224,676	106,496,424	21.7715		.002109705	1,489.11	176,460.12
475	225,625	107,171,875	21.7945	7.8025 7.8079	.002105263	1,492.26 1,495.40	177,205.46
476 477	226,576 227,529	107,850,176 108,531,333	21.8403	7.8134	.002100340	1,498.54	177,952.37 178,700.86
178	228,484	109,215,352	21.8632	7.8188	.002092050	1,501.68	179,450.91
479	229,441	109,902,239	21.8861	7.8243	.002087683	1,504.82	180,202.54
480	230,400	110,592,000	21.9089	7.8297	.002083333	1,507.96	180,955.74
481	231,361	111,284,641	21.9317	7.8352	.002079002	1,511.11	181,710.50
182	232,324	111,980,168	21.9545	7.8406	.002074689	1,514.25	182,466.84
483	233,289	112,678,587	21.9775	7.8460	.002070393	1.517.39	183,224.75
484	234,256	113,379,904	22.0000	7.8514	.002066116	1,520.53	183,984.23
485	235,225	114,084,125	22.0227	7.8568	.002061856	1,523.67	184,745.28
486	236,196	114,791,256	22.0454	7.8622	.002057613	1,526.81	185,507.90
487	237,169	115,501,303	22.0681	7.8676	.002053388	1,529.96	186,272.10
188	238,144	116,214,272	22.0907	7.8730	.002049180	1,533.10	187,037.86
489	239,121	116,930,169	22.1133	7.8784	.002044990	1,536.24	187,805.19
490	240,100	117,649,000	22.1359	7.8837	.002040816	1,539.38	188,574.10
491	241,081	118,370,771	22.1585 22.1811	7.8891 7.8944	.002036660	1,542.52	189,344.57
492 493	242,064	119,095,488 119,823,157	22.1811	7.8944	.002032520	1,545.66 1,548.81	190,116.62
494	243,049 244,036	120,553,784	22.2036	7.9051	.002028398	1,551.95	190,890.24 191,665.43
495	245,025	121,287,375	22.2486	7.9105	.002020292	1,555.09	192,442.18
496	246,016	122,023,936	22.2711	7.9158	.002016129	1,558.23	193,220.51
100		,00,000		1		1-,000.20	

	No.	Square.	Cube.	Sq. Root.	Cu. Root.	Reciprocal.	Circum.	Area.
Ī	4.97	247,009	122,763,473	22.2935	7.9211	.002012072	1,561.37	194,000.41
	498	248,004	123,505,992	22.3159	7.9264	.002008032	1,564.51	194,781.89
l	49 9 50 0	249,001	124,251,499 125,000,000	22.3383	7.9317	.002004008	1,567.65	195,564.93
ı	5 00	250,000	125,751,501	22.3607 22.3830	7.9370 7.9423	.002000000	11,570.80	196,349.54
ı	5 02	251,001 252,004	126,506,008	22.4054	7.9476	.001992032	1,573.94 1,577.08	197,135.72
l	503	253,009	127,263,527	22.4277	7.9528	.001988072	1,580.22	198,712.80
ł	504	254,016	128,024,064	22.4499	7.9581	.001984127	1,583.36	199,503.70
ł	50 5	255,025	128,787,625	22.4722	7.9634	.001980198	1,586.50	200,296.17
1	5 06	256,036	129,554,216	22.4944	7.9686	.001976285	1,589.65	201,090.20
ı	507	257,049	130,323,843	22.5167	7.9739	.001972387	1,592.79	201,885.81
1	508	258,064	131,096,512	22.5389	7.9791	.001968504	1,595.93	202,682.99
١	509 510	259,081 260,100	131,872,229	22.5610 22.5832	7.9843 7.9895	.001964637	1,599.07 1,602.21	203,481.74
1	511	261,121	132,651,000 133,432,831	22.6053	7.9948	.001956947	1,605.35	204,282.06 205,083.95
1	512	262,144	134,217,728	22.6274	8.0000	.001953125	1,608.50	205,887.42
1	513	263,169	135,005,697	22.6495	8.0052	.001949318	1,611.64	206,692.45
1	514	264,196	135,796,744	22.6716	8.0104	.001945525	1,614.78	207,499.05
1	515	265,225	136,590,875	22.6936	8.0156	.001941748	1,617.92	208,307.23
1	516	266,256	137,388,096	22.7156	8.0208	.001937984	1,621.06	209,116.97
- 1	517	267,289	138,188,413	22.7376	8.0260	.001934236	1,624.20	209,928.29
	518 519	268,324 269,361	138,991,832 139,798,359	22.7596 22.7816	8.0311 8.0363	.001930502	1,627.34	210,741.18
	520	270,400	140,608,000	22.8035	8.0415	.001926782	1,630.49 1,633.63	211,555.63
	521	271,411	141,420,761	22.8254	8.0466	.001919386	1,636.77	212,371.66 213,189.26
	522	272,484	142,236,648	22.8473	8.0517	.001915709	1,639.91	214,008.43
	523	273,529	143,055,667	22.8692	8.0569	.001912046	1,643.05	214,829.17
	524	274,576	143,877,824	22.8910	8.0620	.001908397	1,646.19	215,651.49
	525	275,625	144,703,125	22.9129	8.0671	.001904762	1,649.34	216,475.37
	526	276,676 277,729	145,531,576	22.9347	8.0723	.001901141	1,652.48	217,300.82
	527 528	277,729	146,363,183 147,197,952	22.9565 22.9783	8.0774 8.0825	.001897533	1,655.62	218,127.85
	529	279.841	148,035,889	23.0000	8.0876	.001890359	1,658.76 1,661.90	218,956.44 219,786.61
	530	280,900	148,877,001	23.0217	8.0927	.001886792	1,665.04	220,618.34
	531	281,961	149,721,291	23.0434	8.0978	.001883239	1,668.19	221,451.65
	532	283,024	150,568,768	23.0651	8.1028	.001879699	1,671.33	222,286.53
	533	284,089	151,419,437	23.0868	8.1079	.001876173	1,674.47	223,122.98
	534	285,156	152,273,304	23.1084	8.1130	.001872659	1,677.61	223,961.00
	535 536	286,225 287,296	153,130,375 153,990,656	23.1301 23.1517	8.1180 8.1231	.001869159	1,680.75 1,683.89	224,800.59 225,641.75
	537	288,369	154,854,153	23.1733	8.1281	.001862197	1,687.04	226,484.48
	538	289,444	155,720,872	23.1948	8.1332	.001858736	1,690.18	227,328.79
	539	290,521	156,590,819	23.2164	8.1382	.001855288	1,693.32	228,174.66
	540	291,600	157,464,000	23.2379	8.1433	.001851852	1,696.46	229,022.10
	541	292,681	158,340,421	23.2594	8.1483	.001848429	1,699.60	229,871.12
	542	293,764	159,220,088	23.2809	8.1533	.001845018	1,702.74	230,721.71
	543 544	294,849 295,936	160,103,007 160,989,184	23.3024 23.3238	8.1583 8.1633	.001841621	1,705.88 1,709.03	231,573.86 232,427.59
	545	297,025	161,878,625	23.3452	8.1683	.001834862	1,712.17	233,282.89
	546	298,116	162,771,336	23.3666	8.1733	.001831502	1,715.31	234,139.76
	547	299,209	163,667,323	23.3880	8.1783	.001828154	1,718.45	234,998.20
	548	300,304	164,566,592	23.4094	8.1833	.001824818	1,721.59	235,858.21
	549	301,401	165,469,149	23.4307	8.1882	.001821494	1,724.73	236,719.79
-	550	302,500 303,601	166,375,000 167,284,151	23.4521 23.4734	8.1932 8.1982	.001818182	1,727.88	237,582.94
	551 552	303,601	167,284,151	23.4734	8.1982 8.2031	.001814882	1,731.02 1,734.16	238,447.67
	553	305,809	169,112,377	23.5160	8.2081	.001808318	1,737.30	239,313.96 240,181.83
	554	306,916	170,031,464	23.5372	8.2130	.001805054	1,740.44	241,051.26
	555	308,025	170,953,875	23.5584	8.2180	.001801802	1,743.58	241,922.27
	556	309,136	171,879,616	23.5797	8.2229	.001798561	1,746.73	242,794.85
	557	310,249	172,808,693	23.6008	8.2278	.001795332	1,749.87	243,668.99
	558	311,364	173,741,112	23.6220	8.2327	.001792115	1,753.01	244,544.71
	559	312,481	174,676,879	23.6432	8.2377	.001788909	1,756.15	245,422.00
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No.	Square.	Cube.	Sq. Root.	Cu. Root	. Reciprocal.	Circum.	Area.
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560	313,600	175,616,000	23.6643	8.2426	.001785714	1,759.29	246,300.86
561	314,721	176,558,481	23.6854	8.2475	.001782531	1,762.43	247,181.30
562 563	315,844	177,504,328	23.7065	8.2524	.001779359	1,765.58	248,063.30
564	316,969	178,453,547 179,406,144	23.7276 23.7487	8.2573 8.2621	.001776199	1,768.72 1,771.86	248,946.87 249,832.01
565	319,225	180,362,125	23.7697	8.2670	.001769912	1.775.00	250,718.73
566	320,356	181,321,496	23.7908	8.2719	.001766784	1,778.14	251,607.01
567	321,489	182,284,263	23.8118	8.2768	.001763668	1,781.28	252,496,87
568	322,624 323,761	183,250,432	23.8328	8.2816	.001760563	1,784.42	253,388.30
569	323,761	184,220,009	23.8537	8.2865	.001757469	1,787.57	204,281.29
570	324,900	185,193,000	23.8747	8.2913	.001754386	1,790.71	255,175.86
571 572	326,041	186,169,411	23.8956	8.2962	.001751313	1,793.85	256,072.00
573	327,184 328,329	187,149,248 188,132,517	23.9165 23.9374	8.3010 8.3059	.001748252 .001745201	1,796.99 1,800.13	256,969.71 257,868.99
574	329,476	189,119,224	23.9583	8.3107	.001742164	1,803.27	258,769.85
575	330,625	190,109,375	23.9792	8.3155	.001739130		259,672.27
576	331,776	191,102,976	24.0000	8.3203	.001736111		260,576.26
577	332,929	192,100,033	24.0208	8.3251	.001733102		261,481.83
578	334,084	193,100,552	24.0416	8.3300	.001730104		262,388.96
579	335,241	194,104,539	24.0624	8.3348	.001727116	1,818.98	263,297.67
580	336,400	195,112,000	24.0832	8.3396	.001724138	1,822.12	264,207.94
581 582	337,561 338,724	196,122,941	24.1039 24.1247	8.3443	.001721170 .001718213	1,825.27 1,828.41	265,119.79
583	339,889	197,137,368 198,155,287	24.1247	8.3491 8.3539	.001715266		266,033.21 266,948.20
584	341.056	199,176,704	24.1661	8.3587	.001712329		267.864.76
585	342,225	200,201,625	24.1868	8.3634	.001709402		268,782.89
586	343,396	201.230.056	24.2074	8.3682	.001706485		269,702.59
587	344,569	202,262,003	24.2281	8.3730	.001703578		270,623.86
588	345,744	203,297,472	24.2487	8.3777	.001700680	1,847.26	271,546.70
589	346,921	204,336,469	24.2693	8.3825	.001697793		272,471.12
590 591	348,100 349,281	205,379,000 206,425,071	24.2899 24.3105	8.3872 8.3919	.001694915		273,397.10 274,324.66
592	350,464	207,474,688	24.3311	8.3967	.001689189		275,253.78
593	351,649	208,527,857	24.3516	8.4014	.001686341	1,862.96	276,184.48
594	352,836	209,584,584	24.3721	8.4061	.001683502		277,116.75
595	354,025	210,644,875	24.3926	8.4108	.001680672	1,869.25	278,050.58
596	355,216	211,708,736	24.4131	8.4155	.001677852	1,872.39	278,985.99
597	356,409	212,776,173	24.4336	8.4202	.001675042		279.922.97
598 599	357,604	213,847,192	24.4540	8.4249	.001672241		280,861.52
600	358,801 360,000	214,921,799 216,000,000	24.4745 24.4949	8.4296 8.4343	.001669449 .001666667	1,881.81 2 1,884.96 2	281,801.65 282,743.34
601	361,201	217,081,801	24.5153	8.4390	.001663894		283,686.60
602	362,404	218,167,208	24.5357	8.4437	.001661130	1,891.24	284,631.44
603	363,609	219,256,227	24.5561	8.4484	.001658375		285,577.84
604	364,816	220,348,864	24.5764	8.4530	.001655629	1,897.52 2	286,525.82
605	366,025	221,445,125	24.5968	8.4577	.001652893	1,900.66	287,475.36
606	367,236	222,545,016	24.6171	8.4623	.001650165	1,903.81	288,426.48
607 608	368,449 369,664	223,648,543 224,755,712	24.6374	8.4670 8.4716	.001647446	1,906.95 2 1,910.09 2	289,379.17 290,333.43
609	370,881	225,866,529	$24.6577 \\ 24.6779$	8.4763	.001642036		91,289.26
610	372,100	226,981,000	24.6982	8.4809	.001639344		92.246.66
611	373,321	228,099,131	24.7184	8.4856	.001636661		93,205.63
612	374,544	229,220,928	24.7386	8.4902	.001633987	1,922.65 2	94,166.17
613	375,769	230,346,397	24.7588	8.4948	.001631321		95,128.28
614	376,996	231,475,544	24.7790	8.4994	.001628664		96,091.97
615	378,225	232,608,375	24.7992	8.5040	.001626016		97,057.22
616	379,456 380,689	233,744,896 234,885,113	24.8193 24.8395	8.5086 8.5132	.001623377	$ \begin{array}{c cccc} 1,935.22 & 2 \\ 1,938.36 & 2 \end{array} $	98,024.05 98,992.44
618	381.924	236,029,032	24.8596	8.5178	.001618123		99,962.41
619	383,161	237,176,659	24.8797	8.5224	.001615509		00,933.95
620	384,400	238,328,000	24.8998	8.5270	.001612903		01,907.05
621	385,641	239,483,061	24.9199	8.5316	.001610306	1,950.93 3	02,881.73
622	386,884	240,641,848	24.9399	8.5362	.001607717	1,954.07 3	03,857.98
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٧o.	Square.	Cube.	Sq. Root.	Cu. Root.	Reciprocal.	Circum.	Агеа.
23	388,129	241,804,367	24.9600	8.5408	.001605136	1,957.21	304,835.80
24	389,376	242,970,624	24.9800	8.5453	.001602564	1,960.35	305,815.20
25	390,625	244,140,625	25.0000	8.5499	.001600000	1,963.50	306,796.16
26	391,876	245,314,376	25.0200	8.5544	.001597444	1,966.64	307,778.69 308,762.79
27	393,129	246,491,883	25.0400	8.5589	.001594896	1,969.78	308,762.79
28	394,384	247,673,152	25.0599	8.5635	.001592357	1,972.92	309,748.47
29	395,641	248,858,189	25.0799	8.5681	.001589825	1,976.06	310,735.71
30	396,900	250,047,000	25.0998	8.5726	.001587302	1,979.20	311,724.53
31	398,161	251,239,591	25.1197	8.5772	.001584786	1,982.35	312,714.92
32	399,424	252,435,968	25.1396	8.5817	.001582278	1,985.49	313,706.88
33 34	400,689	253,636,137	25.1595	8.5862 8.5907	.001579779 .001577287	1,988.63	314,700.40
	401,956	254,840,104	25.1794		.001574803	1,991.77	315,695.50
35	403,225	256,047,875	25.1992 25.2190	8.5952 8.5997	.001572327	1,994.91 1,998.05	316,692.17
36 37	404,496 405,769	257,259,456 258,474,853	25.2389	8.6043	.001569859	2,001.19	317,690.42 318,690.23
38	407,044	259,694,072	25.2587	8,6088	.001567398	2,004.34	319,691.61
39	408,321	260,917,119	25.2784	8.6132	.001564945	2,007.48	320,694.56
10	409,600	262,144,000	25.2982	8.6177	.001562500	2,010.62	321,699.09
41	410,881	263,374,721	25.3180	8.6222	.001560062	2,013.76	322.705.18
42	412,164	264,609,288	25.3377	8.6267	.001557632	2,016.90	323,712.85
43	413,449	265,847,707	25.3574	8.6312	.001555210	2,020.04	324,722.09
44	414,736	267,089,984	25.3772	8.6357	.001552795	2.023.19	325,732.89
45	416,125	268,336,125	25.3969	8.6401	.001550388	2,026.33	326,745.27
46	417,316	269,585,136	25.4165	8.6446	.001547988	2,029.47	327.759.22
47	418,609	270.840.023	25.4362	8.6490	.001545595	2,032.61	328,774.74 329,791.83
48	419,904	272,097,792	25.4558	8.6535	.001543210	2,035.75	329,791.83
i49	421,201	273,359,449	25.4755	8.6579	.001540832	2,038.89	330,810.49
50	422,500	274,625,000	25.4951	8.6624	.001538462	2,042.04	331,830.72
i51	423,801	275,894,451	25.5147	8.6668	.001536098	2,045.18	332,852.53
552	425,104	277,167,808	25.5343	8.6713	.001533742	2,048.32	333,875.90
553	426,409	278,445,077	25.5539	8.6757	.001531394	2,051.46	334,900.85
554	427,716	279,726,264 281,011,375	25.5734	8.6801	.001529052	2,054.60	335,927.36
355	429,025	281,011,375	25.5930	8.6845	.001526718	2,057.74	336,955.45
556	430,336	282,300,416	25.6125	8.6890	.001524390	2,060.88	337,985.10
357	431,639	283,593,393	25.6320	8.6934 8.6978	.001522070 $.001519751$	2,064.03	339,016.33
358 359	432,964 434,281	284,890,312 286,191,179	25.6515 25.6710	8.7022	.001517451	2,067.17 2,070.31	340,049.13 341,083.50
560	435,600	287,496,000	25.6905	8.7066	.001515152	2,073.45	342,119.44
561	436,921	288,804,781	25.7099	8.7110	.001512859	2,076.59	343,156.95
662	438,244	290,117,528	25.7294	8.7154	.001510574	2,079.73	344,196.03
663	439,569	291,434,247	25.7488	8.7198	.001508296	2,082.88	345,236.69
664	440,896	292,754,944	25.7682	8.7241	.001506024	2,086.02	346,278.91
665	442,225	294,079,625	25.7876	8.7285	.001503759	2,089.16	347,322,70
666	443,556	295,408,296	25.8070	8.7329	.001501502	2,092.30	348,368.07
667	444,899	296,740,963	25.8263	8.7373	.001499250	2,095.44	349,415.00
668	446,224	298,077,632	25.8457	8.7416	.001497006	2,098.58 2,101.73	350,463.51
669	447,561	299,418,309	25.8650	8.7460	.001494768	2,101.73	351,513.59
670	448,900	300,763,000	25.8844	8.7503	.001492537	2,104.87	352,565.24
671	450,241	302,111,711	25.9037	8.7547	.001490313	2,108.01	353,618.45
672	451,584	303,464,448	25.9230	8.7590	.001488095	2,111.15	354,673.24
673	452,929	304,821,217	25.9422	8.7634	.001485884	2,114.29	355,729.60
674	454,276	306,182,024	25.9615	8.7677	.001483680	2,117.43	356,787.54
675	455,625	307,546,875	25.9808	8.7721	.001481481	2,120.58	357,847.04
676	456,976	308,915,776	26.0000	8.7764	.001479290	2,123.72	358,908.11
677	458,329	310,288,733	26.0192	8.7807	.001477105	2,126.86	359,970.75
678	459,684	311,665,752	26.0384	8.7850	.001474926	2,130.00	361,034.97
679	461,041	313,046,839	26.0576	8.7893	.001472754	2,133.14	362,100.75
680	462,400 463,761	314,432,000	26.0768	8.7937 8.7980	.001470588	2,136.28	363,168.11
681	465 194	315,821,241	26.0960 26.1151	8.8023	.001468429	2,139.42	364,237.04
682 683	465,124	317,214,568 318,611,987	26.1131	8.8066	.001464129	2,142.57 $2,145.71$	365,307.54
684	466,489 467,856	320,013,504	26.1534	8.8109	.001461988	2,148.85	366,379.60 367,453.24
685	469,225	321,419,125	26.1725	8.8152	.001451500		368,528.45
300	100,000	021,710,120	~0.1120	0.0104	.001100001	~,101.03	000,040.30

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No.	Square.	Cube.	Sq. Root.	Cu. Root.	Reciprocal.	Circum.	Area.
686	470,596	322.828.856	26.1916	8.8194	.001457726	2,155.13	369,605.23
687	471,969	324,242,703	26.2107	8.8237	.001455604	2,158.27	370,683.59
688	473,344	325,660,672	26.2298	8.8280	.001453488	2,161.42	371,763.51
689	474,721	327,082,769	26.2488	8.8323	.001451379	2,164.56	372,845.00
690	476,100	328,509,000	26.2679	8.8366	.001449275	2,167.70	373,928.07
691 692	477,481 478,864	329,939,371 331,373,888	26.2869 26.3059	8.8408 8.8451	.001447178	2,170.84 2,173.98	375,012.70 376,098.91
693	480,249	332,812,557	26.3249	8.8493	.001443001	2,177.12	377,186.68
694	481,636	334,255,384	26.3439	8.8536	.001440922	2.180.27	378, 276.93
695	483,025	334,255,384 335,702,375	26.3629	8.8578	.001438849	2,183.41	379,366.95
696	484,416	337,153,536	26.3818	8.8621	.001436782	2,186.55	380,459.44
697	485,809	338,608,873	26.4008	8.8663	.001434720	2,189.69	381,553.50
698	487,204	340,068,392	26.4197	8.8706	.001432665	2,192.83	382,649.13
699 700	488,601 490,000	341,532,099 343,000,000	26.4386 26.4575	8.8748 8.8790	.001430615	2,195.97 2,199.11	383,746.33 384,845.10
701	491,401	344,472,101	26.4764	8.8833	.001426534	2,202.26	385,945.44
702	492,804	345,948,408	26.4953	8.8875	.001424501	2,205.40	387,047.36
703	494,209	347,428,927	26.5141	8.8917	.001422475	2,208.54	388,150.84
704	495,616	348,913,664	26.5330	8.8959	.001420455	2,211.68	389,255.90
705	497,025	350,402,625	26.5518	8.9001	.001418440	2,214.82 2,217.96	390,362.52 391,470.72
706 707	498,436 499,849	351,895,816 353,393,243	26.5707 26.5895	8.9043 8.9085	.001416431	2,221.11	392,580.49
708	501,264	354,894,912	26.6083	8.9127	.001412429	2,224.25	393,691.82
709	502,681	356,400,829	26.6271	8.9169	.001410437	2,227.39	394,804.73
710	504,100	357,911,000	26.6458	8.9211	.001408451	2,230.53	395,919.21
711	505,521	359,425,431	26.6646	8.9253	.001406470	2,233.67	397,035.26
712 713	506,944 508,369	360,944,128 362,467,097	26.6833 26.7021	8.9295 8.9337	.001404494 .001402525	2,236.81 2,239.96	398,152.89 399,272.08
714	509,796	363,994,344	26.7208	8.9378	.001402520	2,243.10	400,392.84
715	511,225	365,525,875	26.7395	8.9420	.001398601	2,246.24	401 515 18
716	512,656	367,061,696	26.7582	8.9462	.001396648	2,249.38	402,639.08 403,764.56
717	514,089	368,601,813	26.7769	8.9503	.001394700	2,252.52	403,764.56
718 719	515,524	370,146,232	26.7955	8.9545 8.9587	.001392758	2,255.66 2,258.81	404,891.60 406,020.22
720	516,961 518,400	371,694,959 373,248,000	26.8142 26.8328	8.9628	.001388889	2,261.95	407,150.41
721	519,841	374,805,361	26.8514	8.9670	.001386963	2,265.09	408,282.17
722	521,284 522,729	376,367,048	26.8701	8.9711	.001385042	2,268.23	409,415.50
723	522,729	377,933,067	26.8887	8.9752	.001383126	2,271.37	410,550.40
724 725	524,176	379,503,424	26.9072 26.9258	8.9794 8.9835	.001381215 .001379310	2,274.51 2,277.65	411,686.87 412,824.91
726	525,625 527,076	381,078,125 382,657,176	26.9444	8.9876	.001373310	2,280.80	413,964.52
727	528,529	384,240,583	26.9629	8.9918	.001375516	2,283.94	415,105.71
728	529,984	385,828,352	26.9815	8.9959	.001373626	2,287.08	416,248.46
729	531,441	387,420,489	27.0000	9.0000	.001371742	2,290.22	417,392.79
730 731	532,900	389,017,000	27.0185	9.0041	.001369863	2,293.36 2,296.50	418,538.68 419,686.15
732	534,361 535,824	390,617,891 392,223,168	27.0370 27.0555	9.0082 9.0123	.001366120	2,299.65	420,835.19
733	537,289	393,832,837	27.0740	9.0164	.001364256	2,302.79	421,985.79
734	538,756	395,446,904	27.0924	9.0205	.001362398	2,305.93	423,137.97
735	540,225	397,065,375	27.1109	9.0246	.001360544	2,309.07	424,291.72
736	541,696	398,688,256	27.1293	9.0287	.001358696	2,312.21 2,315.35	425,447.04
737 738	543,169 544,644	400,315,553 401,947,272	27.1477 27.1662	9.0328 9.0369	.001356852	2,318.50	426,603.94 427,762.40
739	546,121	403.583.419	27.1846	9.0410	.001353180	2,321.64	428,922.43
740	547,600	405,224,000	27.2029	9.0450	.001351351	2,324.78	430,084.03
741	549,801	406,869,021	27.2213	9.0491	.001349528	2,327.92	431,247.21
742	550,564	408,518,488	27.2397 27.2580	9.0532	.001347709	2,331.06	432,411.95
743 744	552,049 552 526	410,172,407	27.2580	9.0572	.001345895	2,334.20 2,337.34	433,578.27 434,746.16
745	553,536 555,025	411,830,784 413,493,625	27.2764 27.2947	9.0613 9.0654	.001342282	2,340.49	435,915.62
746	556,516	415,160,936	27.3130	9.0694	.001340483	2,343.63	437,086.64
747	558,009	416,832,723	27.3313	9.0735	.001338688	2,346.77	438,259.24
748	559,504	418,508,992	27.3496	9.0775	.001336898	2,349.91	439,433.41
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١	No.	Square.	Cube.	Sq. Root.	Cu. Root.	Reciprocal.	Circum.	Area.
	749	561,001	420,189,749	27.3679	9.0816	.001335113	2,353.05	440,609.16
1	750	562,500	421,875,000	27.3861	9.0856	.001333333	2,356.19	441,786.47
ı	751	564,001	423,564,751	27.4044	9.0896	.001331558	2,359.34	442,965.35
1	752 753	565,504 567,009	425,259,008 426,957,777	27.4226 27.4408	9.0937 9.0977	.001329787 .001328021	2,362.48 2,365.62	444,145.80 445,327.83
١	754	568,516	428,661,064	27.4591	9.1017	.001326260	2,368.76	446,511.42
1	755	570,025	430,368,875	27.4773	9.1057	.001324503	2,371.90	447,696.59
1	756	571,536	432,081,216	27.4955	9.1098	.001322751	2,375.04	448,883.32
- 1	757	573.049	433,798,093	27.5136	9.1138	.001321004	2,378.19	450,071.63
	758	574,564	435,519,512	27.5318	9.1178	.001319261	2,381.33	451,261.51
	759	576,081	437,245,479	27.5500	9.1218	.001317523	2,384.47	452,452.96
	760	577,600	438,976,000	27.5681	9.1258 9.1298	.001315789	2,387.61	453,645.98
	761 762	579,121 580,644	440,711,081 442,450,728	27.5862 27.6043	9.1238	.001314060	2,390.75 2,393.89	454,840.57 456,036.73
	763	582,169	444,194,947	27.6225	9.1378	.001312636	2,397.04	457,234.46
	764	583,696	445,943,744	27.6405	9.1418	.001308901	2,400.18	458,433.77
	765	585,225	447,697,125	27.6586	9.1458	.001307190	2,403.32	459,634.64
	766	585,225 586,756	449,455,096	27.6767	9.1498	.001305483	2,406.46	460,837.08
	767	588,289	451,217,663	27.6948	9.1537	.001303781	2,409.60	462,041.10
	768	589,824	452,984,832	27.7128	9.1577	.001302083	2,412.74	463,246.69
	769 770	591,361 592,900	454,756,609 456,533,000	27.7308 27.7489	9.1617 9.1657	.001300390 .001298701	2,415.88 2,419.03	464,453.84
	771	594,441	458,314,011	27.7669	9.1696	.001297017	2,422.17	465,662.57 466,872.87
	772	595,984	460,099,648	27.7669 27.7849	9.1736	.001295337	2,425.31	468,084.74
	773	597,529	461,889,917	27.8029	9.1775	.001293661	2,428.45	469,298.18
	774	599,076	463,684,824	27.8209	9.1815	.001291990	2,431.59	470,513.19
	775	600,625	465,484,375	27.8388	9.1855	.001290323	2,434.73	471,729.77
	776	602,176	467,288,576	27.8568	9.1894	.001288660	2,437.88	472,947.92
	777	603,729 605,284	469,097,433 470,910,952	27.8747 27.8927	9.1933 9.1973	.001287001 $.001285347$	2,441.02 2,444.16	474,167.65
	779	606,841	472,729,139	27.9106	9.2012	.001283697	2,444.10	475,388.94 476,611.81
	780	608,400	474,552,000	27.9285	9.2052	.001282051	2,450.44	477,836.24
	781	609,961	476,379,541	27.9464	9.2091	.001280410	2,453.58	479,062.25
	782	611,524	478,211,768	27.9643	9.2130	.001278772	2,456.73	480,289.83
	783	613,089	480,048,687	27.9821	9.2170	.001277139	2,459.87	481,518.97
	784	614,656	481,890,304	28.0000 28.0179	9.2209 9.2248	.001275510 .001273885	2,463.01	482,749.69
	785 786	616,225 617,796	483,736,625 485,587,656	28.0357	9.2287	.001272265	2,466.15 2,469.29	483,981.98 485,215.84
	787	619,369	487,443,403	28.0535	9.2326	.001270648	2,472.43	486,451.28
	788	620,944	489,303,872	28.0713	9.2365	.001269036	2,475.58	487,688.28
	789	622,521	491,169,069	28.0891	9.2404	.001267427	2,478.72	488,926.85
	790	624,100	493,039,000	28.1069	9.2443	.001265823	2,481.86	490,166.99
	791	625,681	494,913,671	28.1247 28.1425	9.2482 9.2521	.001264223	2,485.00	491,408.71
	792 793	627,624 628,849	496,793,088 498,677,257	28.1603	9.2560	$.001262626 \\ .001261034$	2,488.14 2,491.28	492,651.99 493,896.85
	794	630,436	500,566,184	28.1780	9.2599	.001259446	2,491.20	495,143.28
	795	632,025	502,459,875	28.1957	9.2638	.001257862	2,497.57	496,391.27
	796	633,616	504,358,336	28.2135	9.2677	.001256281	2,500.71	497,640.84
	797	635,209	506,261,573	28.2312	9.2716	.001254705	2,503.85	498,891.98
	798	636,804	508,169,592	28.2489	9.2754 9.2793	.001253133	2,506.99	500,144.69
	799 800	638,401 640,000	510,082,399 512,000,000	28.2666 28.2843	9.2793	.001251364	2,510.13 2,513.27	501,398.97 502,654.82
	801	641,601	513,922,401	28.3019	9.2870	.001248439	2,516.42	503,912.25
	802	643,204	515,849,608	28.3196	9.2909	.001246883	2,519.56	505,171.24
	803	644,809	517,781,627	28.3373	9.2948	.001245330	2,522.70	506,431.80
	804	646,416	519,718,464	28.3549	9.2986	.001243781	2,525.84	507,693.94
	805	648,025	521,660,125	28.3725	9.3025	.001242236	2,528.98	508,957.64
	806 807	649,636 651,249	523,606,616 525,557,943	28.3901 28.4077	9.3063 9.3102	.001240695 .001239157	2,532.12 2,535.27	510,222.92 511,489.77
	808	652,864	527,514,112	28.4253	9.3140	.001237624	2,538.41	512,758.19
	809	654,481	529,475,129	28.4429	9.3179	.001236094	2,541.55	514,028.18
	810	656,100	531,441,000	28.4605	9.3217	.001234568	2,544.69	515,299.74
	811	657,721	533,411,731	28.4781	9.3255	.001233046		516,572.87
		1	1				1	

No.	Square.	Cube.	Sq. Root.	Cu. Root.	Reciprocal.	Circum.	Area.
812	659,344	535,387,328	28.4956	9.3294	.001231527	2,550.97	517,847.57
813	660,969	537,367,797	28.5132	9.3332	.001230012	2,554.11	519,123.84
814	662,596	539,353,144	28.5307	9.3370	.001228501	2,557.26	520,401.68
815 816	664,225 665,856	541,343,375 543,338,496	28.5482 28.5657	9.3408 9.3447	.001226994	2,560.40 2,563.54	521,681.10 522,962.06
817	667,489	545,338,513	28.5832	9.3485	.001223990	2,566.68	524,244.63
818	669,124	547,343,432	28.6007	9.3523	.001222494	2,569.82	525,528.76
819	670,761	549,353,259	28.6182	9.3561	.001221001	2,572.96	526,814. 46
820	672,400	551,368,000	28.6356	9.3599	.001219512	2,576.11	528,101.73
821	674,041	553,387,661	28.6531	9.3637 9.3675	.001218027 .001216545	2,579.25 2,582.39	529,390.56 530,680.97
822 823	675,584 677,329	555,412,248 557,441,767	28.6705 28.6880	9.3713	.001215067	2,585.53	531,972.95
824	678,976	559,476,224	28.7054	9.3751	.001213592	2,588.67	533,266.50
825	680,625	561,515,625	28.7228	9.3789	.001212121	2,591.81	534,561.62
826	682,276	563,559,976	28.7402	9.3827	.001210654	2,594.96	535,858.32
827	683,929	565,609,283	28.7576	9.3865	.001209190	2,598.10	537,156.58
828 829	685,584 687,241	567,663,552 569,722,789	28.7750 28.7924	9 3902 9.3940	.001207729	2,601.24 2,604.38	538,456.41 539,757.82
830	688,900	571,787,000	28.8097	9.3978	.001204819	2,607.52	541,060.79
831	690,561	573,856,191	28.8271	9.4016	.001203369	2,610.66	542,365.34
832	692,224	575,930,368	28.8444	9.4053	.001201923	2,613.81	543,671.46
833	693,889	578,009,537	28.8617	9.4091	.001200480	2,616.95	544,979.15
834	695,556	580,093,704	28.8791 28.8964	9.4129 9.4166	.001199041	2,620.09 2,623.23	546,288.40 547,599.23
835 836	697,225 698,896	582,182,875 584,277,056	28,9137	9.4204	.001196172	2,626.37	548,911.63
837	700,569	586,376,253	28.9310	9.4241	.001194743	2,629.51	550 225 61
838	702,244	588,480,472	28.9482	9.4279	.001193317	2,632.65	551 541 15
839	703,921	590,589,719	28.9655	9.4316	.001191895	2,635.80	552,858.26
840	705,600	592,704,000	28.9828	9.4354	.001190476	2,638.94	554,176.94
841	707,281 708,964	594,823,321	29.0000 29.0172	9.4391 9.4429	.001189061	2,642.08 2,645.22	555,497.20 556,819.02
842 843	710,649	596,947,688 599,077,107	29.0345	9.4466	.001186240	2,648.36	558,142.42
844	712,336	601,211,584	29.0517	9.4503	.001184834	2,651.50	559,467.39
845	714,025	603,351,125	29.0689	9.4541	.001183432	2,654.65	560,793.92
846	715,716	605,495,736	29.0861	9.4578	.001182033	2,657.79	562,122.03
847	717,409	607,645,423	29.1033 29.1204	9.4615 9.4652	.001180638 .001179245	2,660.93 2,664.07	563,451.71 564,782.96
848 849	719,104 720,801	609,800,192 611,960,049	29.1376	9.4690	.001177856	2,667.21	566,115.78
850	722,500	614,125,000	29.1548	9.4727	.001176471	2,670.35	567,450.17
851	724,201	616,295,051	29.1719	9.4764	.001175088	2,673.50	568,786.14
852	725,904	618,470,208	29.1890	9.4801	.001173709	2,676.64	570,123.67
853	727,609	620,650,477	29.2062 29.2233	9.4838 9.4875	.001172333 .001170960	2,679.78 2,682.92	571,462.77 572,803.45
854 855	729,316 781,025	622,835,864 625,026,375	29.2404	9.4912	.001169591	2,686.06	574,145.69
856	732,736	627.222.016	29.2575	9.4949	.001168224	2,689.20	575,489.51
857	734,449	629,422,793 631,628,712	29.2746	9.4986	.001166861	2,692.34	576,834.90
858	736,164	631,628,712	29.2916	9.5023	.001165501	2,695.49	578,181.85
859	737,881	633,839,779	29.3087	9.5060	.001164144	2,698.63 2,701.77	579,530.38 580,880.48
860 861	739,600 741,321	636,056,000 638,277,381	29.3258 29.3428	9.5097 9.5135	.001161440	2,704.91	582,232.15
862	743,044	640,503,928	29.3598	9.5171	.001160093	2,708.05	583,585,39
863	744,769	642,735,647	29.3769	9.5207	.001158749	2,711.19	584,940.20
864	746,496	644,972,544	29.3939	9.5244	.001157407	2,714.34	586,296.59
865	748,225	647,214,625	29.4109	9.5281	.001156069 .001154734	2,717.48 2,720.62	587,654.54
866 867	749,956 751,689	649,461,896 651,714,363	29.4279 29.4449	9.5317 9.5354	.001153403	2,723.76	589,014.07 590,375.16
868	753,424	653,972,032	29.4618	9.5391	.001152074	2,726.90	591,737.83
869	755,161	656,234,909	29.4788	9.5427	.001150748	2,730.04	593,102.06
870	756,900	658,503,000	29.4958	9.5464	.001149425	2,733.19	594,467.87
871	758,641	660,776,311	29.5127	9.5501	.001148106	2,736.33	595,835.25
872 873	760,384 762,129	663,054,848 665,338,617	29.5296 29.5466	9.5537 9.5574	.001146789 .001145475	2,739.47 2,742.61	597,204.20 598,574.72
874	763,876	667,627,624	29.5635	9.5610	.001144165	2,745.75	599,946.81
1	,	1 55.,52.,521				1	1,

No.	Square.	Cube.	Sq. Root.	Cu. Root.	Reciprocal.	Circum.	Area.
875 876	765,625 767,376	669,921,875 672,221,376	29.5804 29.5973	9.5647 9.5683	.001142857 .001141553	2,748.89 2,752.04	601,320.47 602,695.70
877	769,129	674,526,133	29.6142	9.5719	.001140251	2,755.18	604,072.50
878 879	770,884 772,641	676,836,152	29.6311	9.5756 9.5792	.001138952	2,758.32 2,761.46	605,450.88 606,830.82
880	774,400	679,151,439 681,472,000	29.6479 29.6648	9.5792	.0011376364	2,764.60	608,212.34
881	776,161	683,797,841	29.6816	9.5865	.001135074	2,767.74	609,595.42
882 883	777,924 779,689	686,128,968 688,465,387	29.6985 29.7153	9.5901 9.5937	.001133787 .001132503	2,770.88 2,774.03	610,980.08 612,366.31
884	781,456	690,807,104	29.7321	9.5973	.001132303	2,777.17	613,754.11
885	783,225	693,154,125	29.7489	9.6010	.001129944	2,780.31	615,143.48
886 887	784,996 786,769	695,506,456 697,864,103	29.7658 29.7825	9.6046 9.6082	.001128668	2,783.45 2,786.59	616,534.42 617,926,93
888	788,544	700,227,072	29.7993	9.6118	.001126126	2,789.73	619,321.01
889	790,321	702,595,369	29.8161	9.6154	.001124859	2,792.88	620,716.66
890 891	792,100 793,881	704,969,000 707,347,971	29.8329 29.8496	9.6190 9.6226	.001123596 $.001122334$	2,796.02 2,799.16	622,113.89 623,512.68
892	795,664	707,932,288	29.8664	9.6262	.001121076	2,802.30	624,913.04
893	797,449 799,236	712,121,957	29.8831	9.6298 9.6334	.001119821	2,805.44	626,314.98 627,718.49
894 895	799,236 801,025	714,516,984 716,917,375	29.8998 29.9166	9.6334	.001118568	2,808.58 2,811.73	627,718.49 629,123.56
896	802,816	719,323,136	29.9333	9.6406	.001116071	2,814.87	630,530.21
897	804,609	721,734,273	29.9500	9.6442	.001114827	2,818.01	631,938.43
898 899	806,404 808,201	724,150,792 726,572,699	29.9666 29.9833	9.6477 9.6513	.001113586 .001112347	2,821.15 2,824.29	633,348.22 634,759.58
900	810,000	729,000,000	30.0000	9.6549	.001111111	2,827.43	636,172.51
901 902	811,801	731,432,701	30.0167	9.6585	.001109878	2,830.58	637,587.01
902	813,604 815,409	733,870,808 736,314,327	30.0333	9.6620 9.6656	.001108647	2,833.72 2,836.86	639,003.09 640,420.73
904	817,216	738,763,264	30.0666	9.6692	.001106195	2,840.00	641,839.95
905 906	819,025 820,836	741,217,625	30.0832 30.0998	9.6727 9.6763	.001104972	2,843.14	643,260.73
907	822,649	743,677,416 746,142,643	30.1164	9.6799	.001103753 .001102536	2,846.28 2,849.42	644,683.09 646,107.01
908	824,464	748,613,312	30.1330	9.6834	.001101322	2,852.57	647,532.51
909 910	826,281 828,100	751,089,429 753,571,000	30.1496	9.6870 9.6905	.001100110 .001098901	2,855.71 2,858.85	648,959.58 650,388.22
911	829.921	756,058,031	30.1828	9.6941	.001091695	2,861.99	651,818.43
912	831,744	758,550,825	30.1993	9.6976	.001096491	2,865.13	653,250.21
913 914	833,569 835,396	761,048,497 763,551,944	30.2159 30.2324	9.7012 9.7047	.001095290	2,868.27 2,871.42	654,683.56 656,118.48
915	837,225	766,060,875	30.2490	9.7082	.001092896	2,874.56	657,554.98
916	839,056	768,575,296	30.2655	9.7118	.001091703	2,877.70	658,993.04
917 918	840,889 842,724	771,095,213 773,620,632	30.2820 30.2985	9.7153 9.7188	.001090513 .001089325	2,880.84 2,883.98	660,432.68 661,873.88
919	844,561	776,151,559	30.3150	9.7224	.001088139	2.887.12	663,316.66
920 921	846,400 848,241	778,688,000	30.3315	9.7259	.001086957	2,890.27	664,761.01
922	850,084	781,229,961 783,777,448	30.3480	9.7294 9.7329	.001085776 .001084599	2,893.41 2,896.55	666,206.92 667,654,41
923	851.929	786,330,467	30.3809	9.7364	.001083423	2,899.69	669,103.47
924 925	853,776 855,625	788,889,024 791,453,125	30.3974 30.4138	9.7400 9.7435	.001082251	2,902.83	670,554.10
926	857,476	794,022,776	30.4302	9.7470	.001081081	2,905.97 2,909.11	672,006.30 673,460.08
927	859,329	796,597,983	30.4467	9.7505	.001078749	2,912.26	674,915.42
1 928	861,184 863,041	799,178,752 801,765,089	30.4631	9.7540 9.7575	.001077586 $.001076426$	2,915.40	676,372.33
930	864,900	804,357,000	30.4750	9.7610	.001075269	2,918.54 2,921.68	677,830.82 679,290.87
931	866,761	806,954,491	30.5123	9.7645	.001074114	2,924.82	680,752.50
932 933	868,624 870,489	809,557,568 812,166,237	30.5287 30.5450	9.7680 9.7715	.001072961 $.001071811$	2,927.96 2,931.11	682,215.69 683,680.46
934	872,356	814,780,504	30.5614	9.7750	.001071611	2,934.25	685,146.80
935	874,225	817,400,375	30.5778	9.7785	.001069519	2,937.39	686,614.71
936 937	876,096 877,969	820,025,856 822,656,953	30.5941 30.6105	9.7829 9.7854	.001068376 $.001067236$	2,940.53 2,943.67	688,084.19 689,555.24
	1	1 22,000,000	3		.552557230	2,010.07	000,000.27

938 879,8 879,8 939 881,7 940 883,6 841,7 940 883,6 841,7 940 883,6 941 885,4 942 887,3 943 889,2 944 891,2 945 946 849,4 950 902,5 951 904,6 950 902,5 953 908,2 954 910,1 955 912,0 956 913,0 956 913,0 956 913,0 956 913,0 956 921,6 956 921,6 956 921,6 956 921,6 963 927,3 954,5 963 927,3 954,5 963 927,3 954,5 965 931,2 946,7 974 948,6 957 974 948,6 957 975 956,8 957,9 954,5 956 977,9 954,5 956 977,9 954,5 958,2 958,4 958,2 958,4 958,2 958,9 958,4 958,2 958,9 958,4 958,2 958,9 958,4 958,2 958,9 958,4 958,2 958,9 958,4 958,2 958,9 958,4 958,2 958,9 958,4 958,2 958,9 958,4 958,2 958,9 958,4 958,2 958,9 958,4 958,2 958,9 958,4 958,2 958,9 958,4 958,2 958,9	uare. Cube.	Sq. Root.	Cu. Root.	Reciprocal.	Circum.	A rea.
940 883.6 885.4 942 887.3 942 887.3 943 889.2 944 881.1 945 883.4 942 887.3 944 881.1 945 883.9 946 894.9 947 896.3 950 902.5 951 904.4 952 966.3 955 951 904.5 955 951 904.5 955 956 957 958 917.7 959 959 958 957 959 958 957 959 959 959 959 959 959 959 959 959	.844 825,293,672	30.6268	9.7889	.001066098	2,946.81	691,027.8
940 883.6 885.4 942 887.3 942 887.3 943 889.2 944 891.1 945 889.7 949 947 896.8 894.9 950 956 951 904.4 952 954 910.1 955 951 912.0 956 951 912.0 956 951 912.0 956 956 913.9 956 957 915.6 913.9 956 957 915.6 956 957 957 959 956 957 957 959 956 957 957 959 956 957 957 959 956 957 959 959 959 959 959 959 959 959 959	,721 827,936,019	30.6431	9.7924	.001064963	2,949.96	692.502.0
941 885,4 887,8 942 887,8 943 889,2 944 889,1 945 889,2 946 893,0 946 894,9 900,6 950 902,5 951 904,6 950 902,5 951 904,6 950 902,5 951 904,6 950 952 966,9 956 913,9 957 915,8 958 917,7 954,5 962 925,4 963 927,3 966 933,1 967 957 959 919,6 959 919,9 959 919,6 938,9 958 917,7 954,5 958 917,7 954,5 958 917,7 954,5 958 917,7 954,5 958 958 958 958 958 958 958 958 958 95	600 830,584,000	30.6594	9.7959	.001063830	2,953.10	693,977.8
942 887,3 89,2 944 889,2 944 889,2 946 894,9 946 894,9 947 896,8 987,9 951 952,6 951 952,6 952,9 954 955 951 951,0 956 957,9 959 957 958,9 959 957 959,9 959 959,9 959,9 959,9 959,9 959,9 959,9 959,9 959,9 959,9 959,9 959,9 959,9 959,9 959,9 959,9 959,9 959,9 958,4 958,9 959,9 958,9 959,9 958,9 959,9		30.6757	9.7993	.001062699	2,956.24	695,455.1
943 889,2 894,2 894,1 891,1 945 894,9 946 894,9 956 913,9 956 913,9 956 913,9 957 956,1 957 956,1 957 956,1 957 956,1 957 956,1 957 956,1 957 956,1 957 956,1 957 956,1 957 957 956,1 957 957 956,1 957 957 957 957 957 957 957 957 957 957		30.6920	9.8028	.001061571	2,959.38	696,934.0
945 883,0 947 894,9 948 894,9 948 894,9 949 900,6 950 902,5 951 904,4 952 906,3 953 908,2 955 912,0 956 913,9 957 915,8 960 921,6 960 921,6 961 923,5 962 925,4 963 927,3 964 929,2 965 931,2 963 933,9 964 929,2 965 931,2 967 935,0 969 938,9 970 940,9 971 942,8 972 944,7 974 948,6 976 952,5 977 954,5 978 968,2 978 968,2 978 968,3 978 968,3 978 968,3 979 968,4 979 968,9 970 971 940,9 971 942,8 972 944,7 974 948,6 976 976 952,5 977 954,5 978 966,9 979 988,9 970 989,9 980 962,3 981 962,3 982 964,3 983 966,2 984 988,2 985 972,1 989 978,1 989 978,1 989 978,1 980 980,9 980 980,9 980 980,9 980 980,9 980 980,9 980 980,9 980 980,9 980 980,9 980 980,9 980 980,9 980 980,9 980 980,9 980 980,9 980 980,9 990 990 990,9 990 990 990,9 990 990 990,9 990 990 990,9 990 990 990,9 990 990 990,9 990 990 990 990,9 990 990 990 990,9 990 990 990 990 990 990 990 990 990 990		30.7083	9.8063	.001060445	2,962.52	698,414.5
946 894,9 896,8 898,7 949 947 886,8 898,7 949 900,6 898,7 951 904,4 952,6 951 905,6 913,9 956 912,0 956 913,9 956 912,0 956 913,9 958 917,7 956,5 931,2 966 933,1 967 956 931,2 966 933,1 967 956,9 956 931,2 966 938,9 970 940,9 956 938,9 970 940,9 956 938,9 970 940,9 958 958 958,9 958 958 958 958 958 958 958 958 958 95	136 841,232,384	30.7246	9.8097	.001059322	2,965.66	699,896.50
946 894,9 947 886,8 898,7 949 990,6 8,9 950 992,5 951 994,4 955 951 994,4 955 951 995,9 956 912,0 956 913,9 957 915,8 958 917,7 956,5 951 991,9 956 931,2 956 931,2 956 957 957 957 957 957 957 957 957 957 957		30.7409	9.8132	.001058201	2,968.81	701,380.1
948 898,7 900,6 950 902,5 901,9 905,9 905,9 906,3 908,2 956 913,9 956 913,9 956 913,9 957 915,8 968 927,4 963 927,4 963 927,4 963 927,4 963 927,4 963 927,4 964 929,2 965 931,2 966 933,0 966 933,0 966 933,0 966,9 977 946,7 956,5 950,6 977 954,5 950,6 978 956,4 979 958,4 968,2	,916 846,590,536	30.7571	9.8167	.001057082	2,971.95	702,865.3 704,352.1
949 900,6 950 902,5 951 904,4 952 906,3 953 908,2 954 910,1 955 912,0 956 913,9 957 915,6 961 923,5 962 925,6 963 927,3 966 933,1 963 927,3 966 933,1 977 940,9 977 940,9 977 954,5 977 954,5 978 956,7 979 958,4 980 900,8 980 900,8 980 900,9 980 9980,9 999 988,9 998 978,1 991 988,9 998 978,1 999 988,9 988 968,2	6,808 849,278,123	30.7734	9.8201	.001055966	2,975.09	704,352.14
950 902.5 951 904.8 952 906.3 953 998.2 954 910.1 955 912.0 956 913.0 956 913.9 957 915.8 958 917.7 960 921.6 961 923.5 962 925.4 963 927.3 964 929.2 956 931.2 965 931.2 966 931.2 967 935.0 968 937.0 969 938.9 970 940.9 971 942.9 971 943.6 976 956.9 977 954.5 977 954.5 978 956.9 978 956.9 979 958.4 979 958.4 979 958.4 979 958.9 971 942.9 971 943.9 972 944.7 974 948.6 975 950.6 976 952.5 977 954.5 977 954.5 978 958.9 978 958.9 978 958.9 989 978.1 989 978.1		30.7896	9.8236	.001054852	2,978.23	705,840.47
951 904.4 952 906.3 953 908.2 954 910.1 955 912.0 956 913.9 957 915.6 960 921.6 961 922.5 962 925.5 961 922.0 963 927.3 964 929.2 965 931.2 966 933.1 967 935.0 970 940.9 970 940.9 971 942.8 972 944.7 973 946.7 974 948.6 975 950.5 977 954.5 977 954.5 978 969 989.2 988 976 92.2 988 976 92.2 988 976 980.2 988 989 978.1 989 989 978.1 989 989 978.1 989 980 999.8 981 962.3 982 984.9 985 970.1 987 971 941.9 988 972.1 987 974 948.6 989 980.2 980 990.9 980 990.9 980 990.9 990 980.1 991 982.0 993 986.0 993 986.0 993 986.0 993 986.0		30.8058	9.8270	.001053741	2,981.37	707,330.37
952 966, 393, 2964 929, 2954 931, 2956 932, 2954 946, 2955, 4960 921, 6960 921, 6960 921, 6960 921, 6960 921, 6960 921, 6960 921, 6960 921, 6960 921, 6960 921, 6960 921, 6960 921, 6960 921, 6960 921, 6960 938, 9966, 937, 935, 0966, 937, 935, 0966, 937, 935, 0966, 937, 935, 936, 497, 936, 4981 962, 3980 966, 2986 977, 936, 4981 962, 3980 966, 2986 977, 936, 4981 962, 3980 966, 2986 977, 936, 4981 962, 3980 966, 2986, 2986 972, 1988, 988, 2988, 988, 2988, 988, 2988, 988,	2,500 857,375,000	30.8221	9.8305	.001052632	2,984.51	708,821.84
953 908,2 908,2 958 958 970,2 986,9 972,1 988,9 972,1 982,0 980,1 9991 982,0 993		30.8383	9.8339	.001051525	2,987.65	710,314.8
954 910.1 955 912.0 956 913.9 957 915.8 958 917.7 959 919.6 961 923.5 962 925.4 963 927.2 966 933.1 967 935.0 968 937.0 971 942.8 972 944.7 974 948.6 976 952.5 977 954.5 978 956.4 979 958.9 971 942.8 979 958.9 971 942.8 971 942.8 972 944.7 974 948.6 976 976 977 974 948.6 976 976 977 974 948.6 977 974 948.6 978 977 954.5 978 978 978 978 978 978 978 978 978 978	6,304 862,801,408	30.8545	9.8374	.001050420	2,990.80	711,809.50
955 912.0 956 913.9 957 915.8 958 917.7 959 919.6 960 921.6 960 921.6 963 927.2 964 929.2 965 931.2 966 931.2 966 931.2 967 935.0 969 938.9 970 940.9 971 942.9 971 944.7 974 948.6 975 950.6 977 954.5 977 954.5 978 966.2 988 978 976.1 989 989 989.8 989 989 978.1 989 978 978 964.2 981 962.3 982 964.3 983 966.2 984 968.2 984 968.2 984 968.2 984 968.2 985 970.2 986 972.1		30.8707	9.8408	.001049318	2,993.94	713,305.69
956 913.9 957 915.8 958 917.7 959 919.6 961 923.5 962 925.5 963 927.3 964 929.2 965 931.2 966 933.1 970 940.9 970 940.9 971 942.8 971 942.8 972 946.7 973 946.7 974 946.7 975 950.6 977 954.5 977 954.5 978 956.4 980 900.8 981 962.3 982 964.3 983 976.1 987 974.1 988 978 978 978 978 978 978 978 978 978		30.8869	9.8443	.001048218	2,997.08	714,803.4
957 915.8 958 917.7 959 919.6 960 921.6 962 925.4 963 927.5 963 927.9 965 931.2 965 931.2 967 935.0 969 938.9 970 940.9 971 942.8 972 944.7 974 948.6 976 952.5 977 954.5 978 956.4 989 980 968.2 984 968.2 985 972.1 989 978.1 981 962.3 982 964.3 983 962.3 984 968.2 985 976 956.4 987 978 968.4 988 978 968.2 988 978 968.2 989 978 968.2 986 979 974.1 988 976.1 989 978 974.1 989 978 974.1 989 978 974.1 989 978 974.1 989 978 979 979 979 979 979 979 979 979		30.9031	9.8477	.001047120	3,000.22	716,302.76
958 917.6 960 919.6 961 923.6 961 923.6 963 927.3 964 929.2 965 931.2 965 931.2 966 933.1 967 935.0 968 937.0 971 944.7 973 946.7 974 948.6 975 950.6 977 954.5 977 954.5 978 956.4 979 988.2 980 969.2 981 962.3 982 964.3 983 966.2 984 968.2 985 972.1 987 974.1 987 974.1 988 978 978.1 989 978.1 980 969.2 981 962.3 982 964.3 983 966.2 984 968.2 985 970.1 987 974.1 989 978.1 989 978.1 989 978.1 980 969.2 986 979.1 981 962.3 982 963.2 984 968.2 985 970.2 986 972.1 989 978.1 989 978.1 989 978.1 989 978.1 989 978.1 989 978.1 989 978.1 980 980.0 990 980.1 991 982.0 993 986.0 993 986.0 994 988.2 995 9990.0 995 9990.0		30.9192	9.8511	.001046025	3,003.36	717,803.66
959 99.6, 6 961 923,5 962 925,4 963 927,6 963 927,9 964 929,2 966 933,1 967 935,0 968 937,0 969 938,9 971 942,8 972 944,7 974 948,6 976 952,5 977 954,5 978 966,4 979 958,4 981 962,3 983 966,2 984 979,1 985 976,1 985 976,1 989 976,1 989 977,1 989 978,1 989 978,1 989 978,1 981 982,0 984 988,2 984 988,2 986 972,1 989 978,1 989 978,1 989 978,1 991 982,0 993 986,0	6,849 876,467,493	30.9354	9.8546	.001044932	3,006.50	719,306.12
960 921.6 961 923.5 962 925.4 963 927.3 964 929.5 965 931.2 965 931.2 966 931.0 967 935.0 971 94.9 971 94.7 974 94.7 974 94.7 974 94.8 975 950.6 977 954.5 977 954.5 977 954.5 977 958.9 978 966.2 984 968.2 984 968.2 984 968.2 984 968.2 984 968.2 984 968.2 984 968.2 984 968.2 984 968.2 984 968.2 984 968.2 985 970.2 986 972.1 989 978.1 989 978.1 989 978.1 989 978.1 989 978.1	7,764 879,217,912	30.9516	9.8580	.001043841	3,009.65	720,810.16 722,315.7
961 923,5 962 925,4 963 927,3 964 929,2 966 933,1 967 935,0 968 937,0 970 940,9 971 942,8 972 944,7 973 946,7 973 946,7 975 956,4 976 932,5 978 956,4 979 938,4 981 962,3 983 966,2 984 972,1 985 976,1 989 977,1 989 978,4 981 962,3 983 966,2 984 988,9 985 970,2 986 972,1 989 978,1 999 980,1 991 982,0		30.9677	9.8614 9.8648	.001042753 .001041667	3,012.79 3,015.93	
962 925,4 963 927,9 963 927,9 964 929,2 965 931,2 967 935,0 969 938,9 970 940,9 971 942,8 972 944,7 974 948,6 976 956,9 977 954,5 977 954,5 978 966,4 981 962,3 982 964,3 983 966,2 984 988,2 986 972,1 988 976,1 989 978,1 989 978,1 989 998,1 991 982,0 991 982,0 992 984,0 993 986,0 994 988,0 993 986,0 994 988,0		30.9839	9.8683	.001041007	3,019.07	723,822.9 725,331.7
963 927.3 964 929.2 965 931.2 966 933.1, 967 935.0 968 937.0 970 940.9 971 942.8 972 944.7 973 946.7 975 950.6 976 935.2 977 954.5 977 954.5 978 956.4 979 980.2 984 968.2 984 968.2 985 970.1 987 974.1 987 974.1 988 966.2 984 968.2 985 970.1 987 974.1 987 974.1 988 975.1 989 978.1 989 978.1 981 962.3 984 968.2 985 970.1 987 974.1 987 974.1 988 976.1 989 978.1 989 978.1 989 978.1 989 978.1 989 978.1 989 978.1 989 978.1 989 978.1 989 978.1 989 978.1 990 980.1 991 982.0 992 984.0 993 986.0 994 988.0 995 9980.0		31.0161	9.8717	.001039501	3,022.21	726,842.0
964 929,2 965 933,1 967 935,0 968 937,0 969 938,9 971 942,8 972 944,7 974 948,6 976 952,5 977 954,5 978 956,4 979 958,4 981 962,3 983 964,3 984 968,2 984 968,2 984 979,1 985 972,1 987 974,1 988 972,1 989 978,1 990 981,0 991 982,0 992 984,0 993 994 998,0 994 998,0 994 998,0 995 999,0 996 998,0 996 998,0 996 998,0 999 998,0		31.0322	9.8751	.001038422	3,025.35	728,353.9
965 931,2 966 933,1 967 935,0 968 937,0 969 938,9 970 940,9 971 942,7 974 948,6 975 950,6 976 952,5 977 954,5 977 954,5 978 964,3 980 960,4 979 978,9 981 962,3 982 964,3 982 964,3 983 966,2 984 968,2 985 970,2 986 972,1 987 974,1 987 974,1 987 974,9 988 978,9 989 988,9 989 988,9 989 988,9 989 988,9 989 988,9 989 988,9 990 980,1 991 982,0 992 984,0 993 986,0 993 986,0	0,296 895,841,344	31.0483	9.8785	.001037344	3,028.50	729,867.3
966 933,1 935,0 968 937,0 969 938,9 970 940,9 971 942,8 972 946,7 975 956,6 976 952,5 978 956,4 979 938,4 968,2 966,2 984 968,2 966,2 984 968,2 966,2 984 968,2 966,2 984 968,2 966,2 984 968,2 966,2 984 968,2 966,2 984 968,2 966,2 984 968,2 966,2 984 968,2 966,2 984 968,2 966,2 984 968,2 966,2 984 968,2 966,2 984 968,2 966,2 984 968,2 966,2 984 968,2 966,2 984 968,2 966,2 985 970,2 985 970,2 986,0 9980,1 989,9 978,1 991 982,0 980,1 991 982,0 9990 980,1 9990 980,1 9991 982,0 9991 982,0 9991 9990,995 9990,995	,225 898,632,125	31.0644	9.8819	.001036269	3,031.64	731,382.4
967 935,0 968 937,0 969 938,9 970 940,9 971 942,9 972 944,7 973 946,7 974 948,6 975 950,6 976 952,5 977 954,5 979 958,4 981 962,3 982 964,3 982 964,3 984 968,2 986 972,1 987 974,1 988 976,1 989 978,1 989 978,1 989 980,0 990 980,0 991 982,0 992 984,0 993 986,0 994 988,0 995 990,0 994 988,0 995 990,0 996,0 996,0 997 998,0 998,0 998,0 998,0 998,0 999,0 990,	3,156 901,428,696	31.0805	9.8854	.001035197	3,034.78	732,899.0
968 937,0 969 938,9 970 940,9 971 942,8 972 946,7 973 946,7 975 950,6 976 952,5 978 956,4 979 958,4 979 958,4 981 962,3 983 966,2 984 968,2 985 972,1 985 972,1 985 976,1 989 978,1 989 980,0 991 982,0 993 986,0 993 986,0 994 988,0 995 990,0 995 990,0		31.0966	9.8888	.001034126	3,037.92	734,417.18
969 938,9 970 940,9 971 942,8 972 944,7 974 948,6 975 950,6 976 950,5 977 954,5 978 956,4 979 958,4 981 962,3 982 964,3 984 968,2 984 979,1 985 972,1 985 972,1 989 978,1 989 978,1 989 984,0 991 984,0 992 984,0 993 986,0 994 988,0 995 990,0 994 998,0 995 999,0 996,0 996,0 996,0 997,0 998,0 999,0 990,0 991 982,0 993 986,0 994 988,0 995 999,0 995 999,0 996,0 996,0 997,0 998,0 998,0 999,0 990,0		31.1127	9.8922	.001033058	3,041.06	735,936.9
970 940,9 971 942,8 972 944,7 973 946,7 975 950,6 975 950,6 977 954,5 977 954,5 977 954,5 978 956,4 979 958,4 979 958,4 980 900,4 981 962,3 982 964,3 982 964,3 982 972,1 987 974,1 987 974,1 989 978,1 989 978,1 989 978,1 989 978,1 981 982,0 984 988,2		31.1288	9.8956	.001031992	3,044.20	737,458.2
971 942.8 972 944.7 973 946.7 974 948.6 976 952.5 977 954.5 978 956.4 979 958.4 981 962.3 983 966.2 984 968.2 985 972.1 985 976.1 989 978.1 989 980,0 990 980,0 991 980,0 991 980,0		31.1448	9.8990	.001030928	3,047.34	738,981.13
972 944,7 973 946,7 974 948,6 975 950,6 976 952,5 977 954,5 977 954,5 979 958,4 979 958,4 981 962,3 982 964,3 983 966,2 984 968,2 985 970,2 986 972,1 987 974,1 989 978,1 991 982,0 993 986,0 993 986,0 994 988,0	2,841 915,498,611	31.1609	9.9024	.001029866	3,050.49	740,505.59
973 946,7 974 948,6 975 950,6 976 952,5 978 956,4 979 958,4 980 960,4 981 962,3 983 966,2 985 972,1 988 977,1 988 976,1 989 978,1 989 978,1 989 978,1 989 978,1 989 978,1 991 982,0 993 986,0 993 986,0 994 988,0	784 918,330,048	31.1769	9.9058	.001028807	3,053.63	742,031.6
974 948.6 975 950.6 976 952.5 977 954.5 978 956.4 979 958.4 981 962.3 982 964.3 982 964.3 984 968.2 986 972.1 987 974.1 988 976.1 989 978.1 990 984.0 993 986.0 994 988.0		31.1929	9.9092	.001027749	3,056.77	743,559.2
975 950,6 976 952,5 977 954,5 978 956,4 980 960,4 981 962,3 983 966,2 984 968,2 985 972,1 988 976,1 988 976,1 989 978,1 990 980,1 991 982,0 993 986,0 994 988,0 993 986,0 994 988,0		31.2090	9.9126	.001026694	3,059.91	745,088.39
977 954,5 978 956,5 978 956,4 979 958,4 980 960,3 981 962,3 982 964,2 983 966,2 984 968,2 985 970,2 986 972,1 989 978,1 989 978,1 990 980,1 991 982,0 992 984,0 993 986,0 994 988,9		31.2250	9.9160	.001025641	3,063.05	746,619.13
978 956,4 979 958,4 980 960,4 981 962,3 982 964,3 983 966,2 984 968,2 985 970,2 986 972,1 988 976,1 989 978,1 989 978,1 990 980,1 991 982,0 993 986,0 994 988,0 993 994,9 994 988,0 995 990,9 995 990,9	2,576 929,714,176	31.2410	9.9194	.001024590	3,066.19	748,151.4
979 958,4 980 960,4 981 962,3 982 964,3 983 966,2 984 968,2 985 972,1 987 974,1 989 978,1 990 980,0 991 982,0 992 984,0 993 986,0 994 988,9 995 990,9		31.2570	9.9228	.001023541	3,069.34	749,685.3
980 960,4 981 962,3 982 964,3 983 966,2 985 970,2 986 972,1 987 974,1 989 978,1 990 980,1 991 982,0 993 986,0 994 988,0		31.2730	9.9261	.001022495	3,072.48	751,220.78
981 962,3 982 964,3 983 966,2 984 968,2 985 970,2 987 974,1 988 976,1 990 980,1 991 982,0 993 986,0 993 986,0 994 988,0 995 990,0	3,441 938,313,739	31.2890	9.9295	.001021450	3,075.62	752,757.80 754,296.40
982 964,3 983 966,2 984 968,2 985 970,2 986 972,1 987 974,1 988 976,1 989 978,1 990 980,1 992 984,0 993 986,0 995 990,0		31.3050	9.9329	.001020408	3,078.76	754,296.40
983 966,2 984 968,2 985 970,2 986 972,1 987 974,1 988 976,1 989 980,1 991 982,0 992 984,0 993 986,0 994 988,0 995 990,0		31.3209	9.9363	.001019168	3,081.90	755.836.56
984 968,2 985 970,2 986 972,1 987 974,1 988 976,1 989 978,1 990 980,1 991 982,0 992 984,0 993 986,0 994 989,0 995 990,0		31.3369	9.9396	.001018330	3,085.04	757,378.30
985 970,2 986 972,1 987 974,1 988 976,1 989 978,1 990 980,1 991 982,0 992 984,0 993 986,0 994 988,0 995 990,0		31.3528	9.9430	.001017294	3,088.19	758,921.61
986 972,1 987 974,1 988 976,1 989 978,1 990 980,1 991 982,0 992 984,0 993 986,0 994 988,0 995 990,0		31.3688	9.9464	.001016260	3,091.33 3,094.47	760,466.48
987 974,1 988 976,1 989 978,1 990 980,1 991 982,0 992 984,0 993 986,0 994 988,0 995 990,0		31.3847 31.4006	9.9497 9.9531	.001015228	3,097.61	762,012.93 763,560.95
988 976,1 989 978,1 990 980,1 991 982,0 992 984,0 993 986,0 994 988,0 995 990,0	2,196 958,585,256		9.9565	.001013171	3,100.75	
989 978,1 990 980,1 991 982,0 992 984,0 993 986,0 994 988,0 995 990,0	1,169 961,504,803 5,144 964,430,272	31.4166 31.4325	9.9598	.001013171	3,103.89	765,110.54 766,661.70
990 980,1 991 982,0 992 984,0 993 986,0 994 988,0 995 990,0	3,121 967,361,669	31.4484	9.9632	.001011122	3,107.04	768,214.44
991 982,0 992 984,0 993 986,0 994 988,0 995 990,0		31.4643	9.9666	.001010101	3,110.18	769,768.74
992 984,0 993 986,0 994 988,0 995 990,0		31.4802	9.9699	.001009082	3,113.32	771,324.61
993 986,0 994 988,0 995 990,0		31.4960	9.9733	.001008065	3,116.46	772,882.06
994 988,0 995 990,0		31.5119	9.9766	.001007049	3,119.60	774,441.07
995 990,0		31.5278	9.9800	.001006036	3,122.74	776,001.66
	0,025 985,074,875	31.5436	9.9833	.001005025	3,125.88	777,563.82
996 992,0	2,016 988,047,936	31.5595	9.9866	.001004016	3,129.03	779,127.54
997 994,0		31.5753	9.9900	.001003009	3,132.17	780,692.84
998 996,0		31.5911	9.9933	.001002004	3,135.31	782,259.71
999 998,0		31.6070	9.9967	.001001001	3,138.45	783,828.15
1000 1,000,0		31.6228	10.0000	.001000000	3,141.59	785,398.16

CIRCUMFERENCES AND AREAS OF CIRCLES FROM 1-64 TO 100.

Diam.	Circum.	Area.	Diam.	Circum.	Area.	Diam.	Circum.	Area.
	.0491	.0002	6	18.8496	28.2744	131	41.2335	135.297
4 37 16	.0982	.0008	61	19.2423	29.4648	13 ¹ / ₄ 13 ¹ / ₄	41.6262	137.887
3.	.1963	.0031	6 1 61	19,6250	30.6797	131	42.0189	140.501
10	.3927	.0123	61	20.0277	31.9191	131	42.4116	143.139
Å	.5890	.0276	64	20.4204	33.1831	13	42.8043	145.802
ĩ	.7854	.0491	6	20.8131	34.4717	131	43.1970	148.490
80-15 - 4-0-15 - 18-15 - 18-15 - 18-15 - 18-15 - 18-15 - 18-15 - 18-15 - 18-15 - 18-15 - 18-15 - 18-15 - 18-15	.9817	.0767	61	21.2058	35.7848	137	43.5897	151,202
a a	1.1781	.1104	6 1	21.5985	37.1224	14	43.9824	153.938
₹.	1.3744	.1503	7	21.9912	38.4846	141	44.3751	156.700
ĩ	1.5708	.1963	71 71	22.3839	39.8713	141	44.7678	159.485
78	1.7671	.2485	7₹	22.7766	41.2826	14	45.1605	162.296
Ŧ	1.9635	.3068	7 ₁	23.1693	42.7184	14	45.5532	165.130
11	2.1598	.3712	71	23.5620	44.1787	14	45.9459	167.990
¥	2.3562	.4418	71	23.9547	45.6636	14#	46.3386	170.874
H	2.5525	.5185	7	24.3474	47.1731	147	46.7313	173.782
7	2.7489	.6013	71	24.7401	48.7071	15	47.1240	176.715
₩	2.9452	.6903	8	25.1328	50.2656	15 1 15 1	47.5167	179.673
1	3.1416	.7854	8 1	25.5255	51.8487	15 1	47.9094	182.655
11	3.5343	.9940	8 <u>I</u>	25.9182	53.4563	15}	48.3021	185,661
11	3.9270	1.2272	8	26.3109	55.0884	15	48.6948	188.692
11 11 11	4.3197	1.4849	8 <u>i</u>	26.7036	56.7451	151	49.0875	191.748
14	4.7124	1.7671	8	27.0963	58.4264	15₹	49.4802	194.828
14	5.1051	2.0739	8₽	27.4890	60.1322	157	49.8729	197.933
1#	5.4978	2.4053	8	27.8817	61.8625	16	50.2656	201.062
17	5.8905	2.7612	9	28.2744	63.6174	16½	50.6583	204.216
2	.6.2832	3.1416	9 <u>1</u>	28.6671	65.3968	16 ¼	51.0510	207.395
2 }	6.6759	3.5466	9‡	29.0598	67.2008	16	51.4437	210.598
21 21 21 21	7.0686	3.9761	91	29.4525	69.0293	16	51.8364	213.825
21	7.4613	4.4301	91	29.8452	70.8823	16	52.2291	217.077
21	7.8540	4.9087	9	30.2379	72.7599	16₹	52.6218	220.354
24	8.2467	5.4119	9	30.6306	74.6621	167	53.0145	223.655
2	8.6394	5.9396	97	31.0233	76.589	17	53.4072	226.981
27	9.0321	6.4918	10	31.4160	78.540	171 171	53.7999	230.331
3	9.4248	7.0686	101	31.8087	80.516	17‡	54.1926	233.706
$\frac{3\frac{1}{4}}{3\frac{1}{4}}$	9.8175	7.6699	101	32.2014	82.516	17	54.5853	237.105
34	10.2102	8.2958	10	32.5941	84.541	17	54.9780	240.529
3	10.6029	8.9462	101	32.9868	86.590	17	55.3707	243.977
31	10.9956	9.6211	104	33.3795	88.664	177	55.7634	247.450
3 1 31	11.3883	10.3206	10	33.7722	90.763	177	56.1561	250.948
3 1	11.7810	11.0447	107	34.1649	92.886	18	56.5488	254.470
4	12.1737 12.5664	11.7933	11 11‡	34.5576	95.033 97.205	181 181	56.9415 57.3342	258.016
41	12.9591	12.5664		34.9503		101		261.587 265.183
41		13.3641	111	35.3430	99.402	181	57.7269	
41	13.3518 13.7445	14.1863	113	35.7357	101.623	181 181	58.1196	268.803
41		15.0330	111	36.1284	103.869	101	58.5123	272.448
41	14.1372 14.5299	15.9043 16.8002	11 1 11 1	36.5211 36.9138	106.139	18‡ 18‡	58.9050 59.2977	276.117 279.811
4	14.9226	17.7206	111	37.3065	108.434 110.754	19	59.6904	283.529
47	15.3153						60.0831	287.272
7.0	15.7080	18.6555 19.6350	$\frac{12}{12\frac{1}{8}}$	37.6992 38.0919	113.098 115.466	191 191	60.4758	291.040
51	16.1007	20.6290	121	38.4846	117.859	197	60.8685	291.040
5 51 51 51	16.1007	20.6290	12	38.8773	120 977	191	61.2612	298.648
51	16.4934	22.6907	12	39.2700	120.277 122.719	191	61.6539	302.489
5	17.2788	23.7583	124	39.2700	125.185	19‡	62.0466	306.355
54	17.6715	24.8505	12	40.0554	125.165	197	62.4393	310.245
51	18.0642	25.9673	127	40.4481	130.192	20	62.8320	314.160
54 54 57	18.4569	27.1086	13	40.8408	132,733	201	63.2247	318.099
	10.4003	21,1000	10	30.0300	102,100	208	00.227	910.099

Di am .	Circum.	Area.	Diam.	Circum.	Area.	Diam.	Circum.	A rea.
201	63.6174	322.063	281	88.3575	621.264	36	113.098	1,017.878
20 1	64.0101	326.051	281	88.7502	626.798	361	113.490	1,024.960
201 201	64.4028 64.7955	330.064 334.102	28 28	89.1429 89.5356	632.357 637.941	361 361	113.883 114.276	1,032.065 1,039.195
201	65.1882	338.164	28	89.9283	643.549	361	114.668	1,046.349
201	65.5809	342.250	28	90.3210	649.182	36	115.061	1,053.528
21	65.9736	346.361	287	90.7137	654.840	36#	115.454	1,060.732
211 211	66.3663 66.7590	350.497 354.657	29 291	91.1064 91.4991	660.521 666.228	36 1 37	115.846 116.239	1,067.960 1,075.213
211	67.1517	358.842	291	91.8918	671.959	371	116.632	1.082.490
21	67.5444	363.051	291	92.2845	677.714	371	117.025	1,089.792
214	67.9371	367.285	291	92.6772	683.494	371	117.417	1,097.118
21# 21#	68.3298 68.7225	371.543	294 294	93.0699 93.4626	689.299 695.128	371 371	117.810 118.203	1,104.469 1,111.844
22	69.1152	375.826 380.134	291	93.8553	700.982	371	118.595	1,119.244
221 221	69.5079	384.466	30	94.2480	706.860	37	118.988	1,126.669
	69.9006	388.822	301	94.6407	712.763	38	119.381	1,134.118
221	70.2933	393.203	301	95.0334	718.690	381 381	119.773	1,141.591
221 221	70.6860 71.0787	397.609 402.038	301 301	95.4261 95.8188	724.642 730.618	381	120.166 120.559	1,149.089 1,156.612
22 1	71.4714	406.494	30	96.2115	736.619	38	120.952	1,164.159
22i	71.8641	410.973	30	96.6042	742.645	384	121.344	1,171.731
23.	72.2568	415.477	304	96.9969	748.695	381	121.737	1,179.327
231 231	72.6495 73.0422	420.004 424.558	31 31‡	97.3896 97.7823	754.769 760.869	387 39	122.130 122.522	1,186.948 1,194.593
231	73.4349	429,135	311	98.1750	766.992	391	122.915	1.202.263
23	73.8276	433.737	311	98.5677	773.140	39 1	123.308 123.700	1,209.958 1,217.677
234	74.2203	438.364	311	98.9604	779.813	39	123.700	1,217.677
23‡ 23‡	74.6130	443.015	31	99.3531 99.7458	785.510	39į 39į		1,225.420 1,233.188
24	75.0057 75.3984	447.690 452.390	31‡ 31‡	100.1385	791.732 797.979	391		1,240.981
241	75.7911	457.115	32	100.5312	804.250	397	125.271	1,248.798
241 241	76.1838	461.864	$\frac{321}{321}$	100.9239	810.545	40	125.664	1,256.640
24	76.5765	466.638	321	101.3166	816.865	401	126.057	1,264.510
241 241	76.9692 77.3619	471.436 476.259	321 321	101.7093 102.1020	823.210 829.579	401 401		1,272.400 1,280.310
24	77.7546	481.107	32	102.4947	835.972	401		1.288.250
247	78.1473	485.979	321	102.8874	842.391	40		1,296.220
25	78.5400	490.875	327	103.280	848.833	401	128.020	1,304.210
25 1 251	78.9327 79.3254	495.796 500.742	33 331	103.673 104.065	855.301 861.792	407 41	128.413 128.806	1,312.220 1,320.260
251	79.7181	505.712	331	104.458	868.309	411	129.198	1,328.320
254	80.1108	510.706	331	104.851	874.850	411	129.591	1,336.410
25	80.5035	515.72 6	331	105.244	881.415	41		1,344.520
25‡ 25‡	80.8962 81.2889	520.769	33‡ 33‡	105.636 106.029	888.005 894.620	411 414	130.376 130.769	1,352.660 1,360.820
26	81.6816	525.838 530.930	33 1	106.029	901.259	411	131.162	1,369.000
261	82.0743	536.048	34	106.814	907.922	417	131.554	1,377.210
261	82.4670	541.190	341	107.207	914.611	42	131.947	1,385.450
261	82.8597	546.356	341	107.600	921.323	421 421		1,393.700
261 261	83.2524 83.6451	551.547 556.763	34 34	107.992 108.385	928.061 934.822	421		1,401.990 1,410.300
262	84.0378	562.003	34	108.778	941.609	421	133.518	1.418.630
267	84.4305	567.267	34	109.171	948.420	42	133.911	1,426.990
27	84.8232	572.557	347	109.563	955.255	421	134.303	1,435.370
271 271	85.2159 85.6086	577.870 583.209	35 351	109.956 110.349	962.115 969.000	42 1 43		1,443.770 1,452,200
271	86.0013	588.571	35₹	110.741	975.909	431		1.460.660
271	86.3940	593.959	35	111.134	982.842	431	135.874	1,469.140
271	86.7867	599.371	35≰	111.527	989.800	431	136.267	1,477.640
27‡ 27‡	87.1794	604.807	35# 35#	111.919 112.312	996.783 1,003.790	431 431	136.660	1,486.170
272	87.5721	610.268					137.052	1,494.730

Diam.	Circum.	Area.	Diam.	Circum.	Area.	Diam.	Circum.	Area.
431	137.838	1,511.910	51#	162.578	2,103.35	591	197 919	2,792.21
44	138.230	1,520.530	511	162.970	2,113.52	594	187.818 187.711	2,803.93
441	138.623	1,529.190	52	163.363	2,123.72	59 1	188.103	2,815.67
44 1 44 1	139.016 139.408	1,537.860	521 521	163.756	2,133.94	60	188.496	2,827.44
441	139.801	1,546.56 1,555.29	521	164.149 164.541	2,144.19 2,154.46	60 1 601	188.889 189.281	2,839.23 2,851.05
441	140.194	1,564.04	521	164.934	2,164.76	60 1	189.674	2,862.89
443	140.587	1,572.81	52	165.327	2,175.08	601	190.067	2,874.76
447 45	140.979 141.372	1,581.61 1,590.48	52 1 521	165.719 166.112	2,185.42 2,195.79	601 601	190.459 190.852	2,886.65 2,898.57
451	141.765	1,599.28	53	166.505	2,206.19	601	191.245	2,910.51
451	142.157	1,608.16	531	166.897	2,216.61	61	191.638	2,922.47
451	142.550	1,617.05	531	167.290	2,227.05	61	192.030	2,934.46
451 451	142.943 143.335	1,625.97 1,634.92	531 531	167.683 168.076	2,237,52 2,248.01	61 1 61 1	192.423 192.816	2,946.48 2,958.52
45	143.728	1,643.89	531	168.468	2,258.53	611	193.208	2,970.58
457	144.121	1,652.89	53	168.861	2,269.07	61	193.601	2,982.67
46	144.514	1,661.91	537	169.254	2,279.64	61#	193.994	2,994.78
46) 46	144.906 145.299	1,670.95 1.680.02	54 541	169.646 170.039	2,290.23 2,300.84	61‡ 62	194.386 194.779	3,006.92 3,019.08
461	145.692	1,689.11	541	170.432	2,311.48	621	195.172	3,031.26
46	146.084	1,698.23	54	170.824	2,322.15	62 1	195.565	3,043.47
464	146.477	1,707.37 1,716.54	541	171.217	2,332.83	62	195.957	3,055.71
46‡ 46‡	146.870 147.262	1,725.73	541 541	171.610 172.003	2,343.55 2,354.29	621 621	196.350 196.743	3,067.97 3,080.25
47	147.655	1,734.95	541	172.395	2,365.05	62	197.135	3,092.56
471	148.048	1,744.19	55	172.788	2,375.83	621	197.528	3,104.89
471	148.441	1,753.45	551	173.181	2,386.65	63	197.921	3,117.25
47 47	148.833 149.226	1,762.74 1,772.06	551 551	173.573 173.966	2,397.48 2,408.34	631	198.313 198.706	3,129.64 3,142.04
47	149.619	1,781.40 1,790.76	551	174.359	2,419.23	631	199.099	3,154.47
47	150.011	1,790.76	55	174.751	2,430.14	631	199.492	3,166.93
47 1 48	150.404 150.797	1,800.15 1,809.56	55‡ 55‡	175.144 175.537	2,441.07	631 631	199.884 200.277	3,179.41 3,191.91
481	151.189	1,819.00	56	175.930	2,452.03 2,463.01	634	200.670	3,204.44
481	151.582	1,828.46	561 561	176.322	2,474.02	64	201.062	3,217.00
48j	151.975	1,837.95	561	176.715	2,485.05	641 641	201.455	3,229.58
481 481	152.368 152.760	1,847.46 1,856.99	561 561	177.108 177.500	2,496.11 2,507.19	64	201.848 202.240	3,242.18 3,254.81
48	153.153	1,866.55	56	177.893	2,518.30	641	202.633	3,267.46
487	153.546	1,876.14	56 1	178.286	2,529.43	644	203.026	3,280.14
49	153.938	1,885.75	567	178.678	2,540.58	643	203.419	3,292.84
491 491	154.331 154.724	1,895.38 1,905.04	57 571	179.071 179.464	2,551.76 2,562.97	64 7 65	203.811 204.204	3,305.56 3,318.31
49	155.116	1,914.72	571 571	179.857	2,574.20	651	204.597	3.331.09
491	155.509	1,924.43	57	180.249	2,585.45	65 <u>I</u>	204.989	3,343.89
491 491	155.902 156.295	1,934.16 1,943.91	571	180.642	2,596.73 2,608.03	651 651	205.382 205.775	3,356.71
49	156.687	1,953.69	57# 57#	181.035 181.427	2,619.36	654	206.167	3,369.56 3,382.44
50	157.080	1,963.50	571	181.820	2,630.71	651	206.560	3,395.33
501	157.473	1,973.33	58	182.213	2,642.09	657	206 953	3,408.26
50 1 504	157.865 158.258	1,983.18 1,993.06	581 581	182.605 182.998	2,653.49 2,664.91	661	207.346 207.738	3,421.20 3,434.17
504	158.651	2,002.97	581	183.391	2,676.36	661	208.131	3,447.17
50	159.043	2,012.89	58 1	183.784	2,687.84	661	208.524	3,460.19
50#	159.436	2,022.85	584	184.176	2,699.33	661	208.916	3,473.24
50 1 51	159.829 160.222	2,032.82 2,042.83	58‡ 58‡	184.569 184.962	2,710.86 2.722.41	66‡	209.309 209.702	3,486.30 3,499.40
511	160.614	2,052.85	59	185.354	2,733.98	667	210.094	3,512.52
511	161.007	2,062.90	59 1	185.747	2.745.57	67	210.487	3,525.66
51# 51#	161.400 161.792	2,072.98 2,083.08	59 1	186.140 186.532	2,757.20 2,768.84	671 671	210.880 211.273	3,538.83 3,552.02
514	161.792	2,083.08	591 591	186.925	2,768.84 2,780.51	671	211.273	3,565.24
1	1		1					,000.21

674 674 675 68 681 681	212.058 212.451 212.843 213.236 213.629	3,578.48 3,591.74 3,605.04	751					
67# 67# 68 68# 68#	212.843 213.236 213.629			236.798	4,462.16	83 <u>1</u>	261.538	5,443.26
67 ² 68 681 681	213.236 213.629	3,000.02	751 751	237.191 237.583	4,476.98 4.491.81	831	261.931	5,459.62
68 681 681		3,618.35	75	237.976	4,506.67	831 831	262.324 262.716	5,476.01 5,492.41
681 :		3,631.69	75	238.369	4,521.56	83∦	263.109	5,508.84
	214.021 214.414	3,645.05 3,658.44	76 761	238.762 239.154	4,536.47 4,551.41	83 1 84	263.502 263.894	5,525.30 5,541.78
	214.807	3,671.86	761	239.547	4,566.36	841	264.287	5,558.29
	215.200 215.592	3,685.29 3,698.76	761 761	239.940 240.332	4,581.35	841	264.680	5,574.82
	215.985	3,712.24	76	240.725	4,596.36 4,611.39	841 841	265.072 265.465	5,591.37 5,607.95
	216.378	3,725.75	761	241.118	4,626.45	84	265.858	5,624.56
69 69‡	216.770 217.163	3,739.29 3,752.85	76 1 77	241.510 241.903	4,641.53 4,656.64	84‡ 84‡	266.251 266.643	5,641.18 5,657.84
	217.556	3,766.43	771	242.296	4,671.77	85	267.036	5,674.51
	217.948	3,780.04	771	242.689	4,686.92	851	267.429	5,691.22
	218.341 218.734	3,793.68 3,807.34	77# 77#	243.081 243.474	4,702.10 4,717.31	85¼ 85¾	267.821 268.214	5,707.94 5,724.60
694	219.127	3,821.02	77	243.867	4,732.54	85 i	268.607	5,724.69 5,741.47
	219.519 219.912	3,834.73 3,848.46	771 771	244.259 244.652	4,747.79 4,763.07	854	268.999	5,758.27
	220.305	3,862.22	78	245.045	4,778.37	85≩ 85≩	269.392 269.785	5,775.10 5,791.94
701 1	220.697	3,876.00	78 1	245.437	4,793.70	86	270.178	5,808.82
	221.090 221.483	3,889.80 3,903.63	78↓ 78↓	245.830 246.223	4,809.05 4,824.43	861 861	270.570 270.963	5,825.72 5,842.64
70	221.875	3,917.49	781	246.616	4,839.83	861	271.356	5,859.59
	222.268	3,931.37	78	247.008	4,855.26	86≟	271.356 271.748	5,876.56
	222.661 223.054	3,945.27 3,959.20	78≇ 78¥	247.401 247.794	4,870.71 4,886.18	861 861	272.141 272.534	5,893.55 5,910.58
711 :	223.446	3,973.15	79	248.186	4,901.68	867	272.926	5,927.62
	223.839	3,987.13	791	248.579	4,917.21	87	273.319	5,944.69
	224.232 224.624	4,001.13 4,015.16	79 1 79	248.972 249.364	4,932.75 4,948.33	871 871	273.712 274.105	5,961.79 5,978.91
71 :	225.017	4,029.21	79 <u>i</u>	249.757	4,963.92	87	274.497	5,996.05
	225.410 225.802	4,043.29 4,057.39	791 791	250.150 250.543	4,979.55 4,995.19	871	274.890	6,013.22
72	226.195	4,071.51	791	250.935	5,010.86	871 871	275.283 275.675	6,030.41 6,047.63
721	226.588	4,085.66	80	251.328	5,026.56	87	276.068	6,064.87
72± 72± 72±	226.981 227.373	4,099.84 4,114.04	801 801	251.721 252.113	5,042.28 5,058.03	88	276.461 276.853	6,082.14
721 1	227.766	4.128.26	801	252.506	5,073.79	881 881	277.246	6,099.43 6,116.74
	228.159	4,142.51	801	252.899	5,089.59	88}	277.629	6,134.08
	228.551 228.944	4,156.78 4,171.08	80∦ 80 1	253.291 253.684	5,105.41 5,121.25	88i 88i	278.032 278.424	6,151.45 6,168.84
73	229.337	4,185.40	80 ²	254.077	5,137.12	88	278.817	6.186.25
	229.729	4,199.74	81	254.470	5,153.01	887	279.210	6,203.69 6,221.15
	230.122 230.515	4,214.11 4,228.51	811 811	254.862 255.255	5,168.93 5,184.87	89 891	279.602 279.995	6,221.15 6,238.64
73 i	230.908	4,242.93	81	255.648	5,200.83	89 <u>†</u>	280.388	6,256.15
	231.300 231.693	4,257.37 4,271.84	811 811	256.040 256.433	5,216.82 5,232.84	891 891	280.780 281.173	6,273.69
731	232.086	4,286.33	81∄	256.826	5,248.88	894	281.566	6,291.25 6,308.84
74	232.478	4,300.85	817	257.218	5,264.94	893	281.959 l	6,326.45
	232.871 233.264	4,315.39 4,329.96	82 821	257.611 258.004	5,281.03 5,297.14	89 7 90	282.351 282.744	6,344.08 6,361.74
741	233.656	4,344.55	82 1	258.397	5,313.28	901	283.137	6,379.42
	234.049 234.442	4,359.17 4,373.81	821 821	258.789	5,329.44	901	283.529	6,397.13
742	234.835	4,388.47	821	259.182 259.575	5,345.63 5,361.84	901 901	283.922 284.315	6,414.86 6,432.62
74%	235.227	4,403.16	82 1	259.967	5,378.08	901	284.707	6,450.40
	235.620 236.013	4,417.87 4,432.61	82 7 83	260.360 250.753	5,394.34 5,410.62	90 1 907	285.100 285.493	6,468.21
	236.405	4,447.38	83 ₁	261.145	5,426.93	91	285.886	6,486.04 6,503.90

	1			1	1			
Diam.	Circum.	Area.	Diam.	Circum.	Area.	Diam.	Circum.	Area.
911	286.278	6,521.78	941	295.703	6,958.26	971	305.128	7,408.89
911	286.671	6,539.68	941	296.096	6,976.76	971	305.521	7,427.97
91	287.064	6,557.61	94	296.488	6,995.28	97	305.913	7,447.08
911	287.456	6,575.56	941	296.881	7,013.82	97	306.306	7,466.21
91	287.849	6,593.54	944	297.274	7,032.39	97	306.699	7,485.37
91#	288.242	6,611.55	941	297.667	7,050.98	97#	307.091	7,504.55
91;	288.634	6,629.57	941	298.059	7,069.59	97‡	307.484	7,523.75
92	289.027	6,647.63	95	298.452	7,088.24	98	307.877	7,542.98
921	289.420	6,665.70	951	298.845	7,106.90	981	308.270	7,562.24
921	289.813	6,683.80	954	299.237	7,125.59	981	308.662	7,581.52
924	290.205	6,701.93	95 i	299.630	7,144.31	98 i	309.055	7,600.82
921	290.598	6,720.08	95	300.023	7,163.04	98 <u>i</u>	309.448	7,620.15
924	290.991	6,738.25	954	300.415	7,181.81	98#	309.840	7,639.50
924	291.383	6,756.45	95 1	300.808	7,200.60	98‡	310.233	7,658.88
927	291.776	6,774.68	951	301.201	7,219.41	987	310.626	7.678.28
93	292.169	6,792,92	96	301.594	7.238.25	99	311.018	7.697.71
931	292.562	6.811.20	961	301.986	7,257.11	991	311.411	7.717.16
93 I	292.954	6,829.49	96 I	302.379	7,275.99	991	311.804	7,736.63
931	293.347	6,847.82	961	302,772	7,294.91	991	312.196	7,756.13
93	293.740	6,866.16	961	303.164	7,313.84	994	312.589	7,775.66
934	294.132	6.884.53	964	303.557	7.332.80	994	312.982	7,795.21
931	294.525	6,902.93	961	303.950	7,351.79	994	313.375	7,814.78
937	294.918	6.921.35	967	304.342	7,370.79	997	313.767	7,834.38
94	295.310	6,939.79	97	304.735	7,389.83	100	314.160	7,854.00

The preceding table may be used to determine the diameter when the circumference or area is known. Thus, the diameter of a circle having an area of 7,200 sq. in. is approximately \$5\frac{1}{2}\$ in.

A GLOSSARY OF MINING TERMS.

The present glossary is a combination of glossaries of mining terms contained in the following works: Coal and Metal Miners' Pocketbook, Fifth Edition; Raymond's Glossary of Mining and Metallurgical Terms; Powers' Pocketbook for Miners and Metallurgists: Locke's Miners' Pocketbook, Vol. A.C. Second Pennsylvania Geological Survey; Ilhseng's Manual of Mining; Chism's Encyclopedia of Mexican Mining Law: a Glossary of Terms as Used in Coal Mining, by W. S. Gresley: 11th Annual Report of the State Mine Inspector of Missouri; Bullman's Colliery Working and Management; Reynolds' Handbook of Mining Laws; Report of the Mine Inspector of Tennessee for 1897; Smithsonian Report for 1886; together with a large number of words which have been added from various stray sources. It is impossible to quote the authority for each definition, as many of the definitions are combinations from a number of authors. Where such different definitions have given distinctly different meanings, each one has been included, but where there has been expressed merely a slight shade of difference, the definition agreeing most closely with current American practice has been taken, or else modified to suit such practice. The foreign words selected are those with which an American is most likely to come in contact, and this portion of the glossary is, of course, not exhaustive. For the large number of purely local terms used in the several coal fields of Great Britain, the reader is referred to Mr. Gresley's glossary.

ABA

GLOSSARY.

Abattis (Leicester).-Cross-packing of branches or rough wood, used to keep roads open for ventilation.

Abra (Spanish).—Fissure in a lode, unfilled or only partially filled.

Abranica (Spanish).—Copper sulphides.

Absolute Pressure.—The pressure reckoned from a vacuum.

Absolute Temperature.—The temperature reckoned from the absolute zero.

—459.22 F. or —273° C.

—459.2° F. 07 —27.5° C.

Accompt (Cornish).—Settling day or place.

Achicar (Mexican).—To diminish the quantity of water in any gallery or working, generally by carrying it out in buckets or in leather bags.

Achicadores.—Laborers employed for said purpose. Achichinques.—Same as Achicadores. Also applied to hangers-on about police courts, etc.

Such people as are generally called strikers in the United States.

Acreage Rent (English).—Royalty or rent for working minerals.

Adarme (Mexican).—A weight for gold, about 1.8 grams.

Addlings (North of England).—Earnings.

Ademador (Spanish).—Mine carpenter, or timberman. Ademar (Spanish).—To timber.

Adit.—A nearly horizontal passage from the surface, by which a mine is entered and unwatered with just sufficient slope to insure drainage. In the United States, an adit driven across the measures is usually called a tunnel, though the latter, strictly speaking, passes entirely through a hill, and is open at both ends. Adobe.—Sun-dried brick.

Adventurers.—Original prospectors.

Adverse.—To oppose the granting of a patent to mining claim.

Adze.—A curved cutting instrument for dressing timber.

Aerage (French).—Ventilation.

Acrometers.—The air pistons of a Struve ventilator.

Aerophore.—The name given to an apparatus that will enable a man to enter places in mines filled with explosive or other deadly gases, with safety.

Afterdamp.—The gaseous mixture resulting from an explosion of firedamp.

Agent—The manager of a mining property.

Agent.—The manager of a mining property.

Agitator.—A mechanical stirrer used in pan amalgamation.

Ahondar (Spanish).-To sink.

Air .- The current of atmospheric air circulating through and ventilating the workings of a mine.

Air Box.-Wooden tubes used to convey air for ventilating headings or

sinkings or other local ventilation.

Air Compartment.—An air-tight portion of any shaft, winze, rise, or level, used for improving ventilation.

Air-Course.—See Airway.

Air Crossing. - A bridge that carries one air-course over another.

Air Cushion .- A spring caused by confined air.

Air Door .- A door for the regulation of currents of air through the workings of a mine.

Air-End Way (Locke).—Ventilation levels run parallel with main level.

Air Furnace.—A reverberatory furnace in which to smelt lead.

Air Gates (Locke).—(1) Underground roadways, used principally for venti-lating purposes. (2) An air regulator. Air Head (Staff).—Ventilation ways.

Air Heading.—An airway.

Air Hole (Powers).—A hole drilled in advance to improve ventilation by

communication with other workings or the surface.

Airless End.—The extremity of a stall in longwall workings in which there is no current of air, or circulation of ventilation, but which is kept pure by diffusion and by the ingress and egress of cars, men, etc.

Air Level.—A level or airway of former workings made use of in subsequent

deeper mining operations for ventilating purposes. Air Oven.—A heated chamber for drying samples of ore, etc.

Air Pipe.—A pipe made of canvas or metal, or a wooden box used in conveying air to the workmen, or for rock drills or air locomotives.

Air-Shaft.—A shaft or pit used expressly for ventilation.
Air Slit (Yorks).—A short head between other air heads.

Air Sollar.—A brattice carried beneath the tram rails or road bed in a heading or gangway.

Air Stack.—A stack or chimney built over a shaft for ventilation.

Airway.—Any passage through which air is carried.

Aitch Piece.—Parts of a pump in which the valves are fixed.

Albanil (Spanish).—Mason.
Albayalde (Spanish).—White lead.

Alberti Furnace.—A continuous reverberatory for mercury ores.

Alcam (Wales).—Tin. Alive (Cornish).—Productive.

A homogeneous mixture of two or more metals by fusion.

Alluvial Gold.—Gold found associated with water-worn material. Alluvium.—Gravel, sand, and mud deposited by streams.

Almadeneta (Spanish).-Stamp head.

Almagre (Spanish).—Red ocher.

Alternating Motion.—Up and down, or backward and forward motion.

Alto (Mexican).—The hanging wall of a vein. See Respatdos. Aludel (Spanish).—Earthen condenser for mercury.

Amalgam.—An alloy of quicksilver with some other metal.

Amalgamation.—Absorption of gold and silver by mercury.

Amalgamator.—One that amalgamates gold and silver ores.

Amygdaloidal.—Almond-shaped.

Analysis.—The determination of the original elements and the proportions of each in a substance.

Anemometer.—An instrument used for measuring the velocity of a ventilating current.

Angle Beam.—A two-limbed beam used for turning angles in shafts, etc. Anhydrous.—Without water in its composition.

Anneal.—To toughen metals, glass, etc. by first heating and then cooling

very slowly. Anthracite.—A variety of coal containing a small percentage of volatile

matter.

Anticline.—A flexure or fold in which the rocks on the opposite sides of the fold dip away from each other, like the two legs of the letter A. The inclination on one side may be much greater than on the opposite side. An anticlinal is said to be overturned when the rocks on both sides dip in the same direction.

Anticlinal Axis.—The ridge of a saddle in a mineral vein, or the line along the summit of a vein, from which the vein dips in opposite directions.

Anticlinal Flexure; Anticlinal Fold.—An anticline.

Antiguos, Los (Mexican).—The Spanish or Indian miners of colonial times. Antimony Star.—The metal antimony when crystallized showing fern-like markings on the surface.

Aparadores (Mexican).—Persons that rewash or rework tailings from silver

Aparejo (Mexican).-A pack saddle. Any rough-and-ready apparatus for moving and adjusting heavy timbers, etc.

Aperos (Mexican).—All kinds of mining supplies in general. Aperador.—A

storekeeper.

Apex.—The landing point at the top of a slope or inclined plane, the knuckle; also, the top of an anticlinal. In the U. S. Revised Statutes, the end or edge of a vein nearest the surface.

A pique (Mexican).—Perpendicular.

Apolvillados (Spanish).—Superior ores.

Apron (English).—(1) A covering of timber, stone, or metal, to protect a surface against the action of water flowing over it. (2) A hinged extension

to a loading chute.

Aprons.—Stamp-battery copper plates.

Aqua Fortis.—Nitric acid.

Aqua Regia.—A mixture of hydrochloric acid and nitric acid.

Aqueduct.—An artificial elevated way for carrying water.

Arajo (Mexican).-See Hatajo.

Arch (Cornish).—Portion of lode left standing to support hanging wall, or because too poor.

Archean.—An early period of geological time.

Arching.-Brickwork or stonework forming the roof of any underground roadway. Arenaceous.—Sandy; rocks are arenaceous when they contain a considerable

percentage of sand.

Arends Tup.—An inverted siphon for drawing molten lead from a crucible or furnace.

Arenillas (Spanish).-Refuse earth.

Argentiferous .- Silver-bearing.

Argillaceous.-Clayey; rocks are argillaceous when they contain a considerable percentage of clay, or have some of the characteristics of clay. Argol.-Crude tartar deposited from wine.

Arian (Wales) .- Silver.

Arm.—The inclined leg of a set of timber.
Arrage (North England).—Sharp corner.

Arrastre.—A circular trough in which drags are pulled round by being connected with a central revolving shaft by an arm and chain. Used for grinding and amalgamating ores. Arrastre de cuchara, spoon arrastre; de marca, large arrastre; de mula, mule-power arrastre.

Arrastrar (Mexican).-To drag along the ground. Arrastrar el Agua.-To almost completely exhaust the water in a sump or working.

Arroba (Mexican).-25 lb.

Artesian Well.—An artificial channel of escape, made by a bore hole, for a

subterranean stream, subject to hydrostatic pressure.

Ascensional Ventilation.—The arrangement of the ventilating currents in such a manner that the air shall continuously rise until reaching the bottom of the upcast shaft. Particularly applicable to steep seams. Ashlar.-A facing of cut stone applied to a backing of rubble or rough

masonry or brickwork.

Aspirail (French).—Opening for ventilation. Assay.—The determination of the quality and quantity of any particular

substance in a mineral. Assayer.—One who performs assays.

Assessment Work.—The annual work necessary to hold a mining claim.

Astell.—Overhead boarding in a gallery.

Astyllen (Cornish).—Small dam in an adit; partition between ore and deads on grass.

Atacador (Mexican).—A tamping bar or tamping stick.

Atecas (Mexican).—Same as Achicadores, etc. Atierres (Spanish).—Refuse rock or dirt inside a mine.

Attle (Cornish).—Refuse rock.
Attle (Addle).—The waste of a mine.

Attrition.—The act of wearing away by friction.

Auger Stem.—The iron rod or bar to which the bit is attached in rope drilling. Auget.—Priming tube.

Aur (Wales).-Gold.

Auriferous.-Gold-bearing.

Ausscharen (German).-Junction of lodes.

Auszimmern (German).—Timbering.

Average Produce (Cornish).—Percentage of fine copper in ore.

Average Standard (Cornish).—Price of pure copper in ore.

Aviador (Spanish).—One who provides the capital to work a mine. Avio.—Money furnished to the proprietors of a mine to work the mine, by another person, the Aviador. Avio Contract.-A contract between two parties for working a mine by which one of the parties, the aviador, furnishes the money to the proprietors for working the mine.

Axis.—An imaginary line passing through a body that may be supposed to

revolve around it.

Azimuth.—The azimuth of a body is that arc of the horizon that is included between the meridian circle at the given place and a vertical plane passing through the body. It is always measured from due north around to the right.

Azogue (Spanish).-Mercury. Azogueria.-Amalgamating works. Amalgamator. The person in charge of a patio works. Azogues.-Free

milling ores.

Avoic.—The age of rocks that were formed before animal life existed.

ck.—(1) A plane or cleavage in coal, etc., having frequently a smooth parting and some sooty coal included in it. (2) The inner end of a heading or gangway. (3) To throw back into the gob or waste the small slack, dirt, etc. (4) To roll large coals out of a waste for loading into cars. etc. Balance.—A self-acting incline in the mine, where a balance car and a carriage in which the mine car is placed are used. The loaded car upon the corriers will hotel the belance are and the belance car will hotel the

the carriage will hoist the balance car, and the balance car will hoist the carriage and empty car.

***ackbye Work.—Work done between the shaft and the working face, in

Contradistinction to face work, or work done at the face.

Lek Casing.—A wall or lining of dry bricks used in sinking through drift deposits, the permanent walling being built up within it. The use of timber cribs and planking serves the same purpose.

cack End (England).—The last portion of a jud.

cacking.—(1) The rough masonry of a wall faced with finer work. (2) Earth deposited behind a retaining wall, etc. (3) Timbers let into notches in the rock across the top of a level.

acking Deals.—Deal boards or planking placed at the back of curbs for supporting the sides of a shaft that is liable to run.

ack Joint.—Joint plane more or less parallel to the strike of the cleavage,

and frequently vertical.

**acklash.—(1) Backward suction of air-currents produced after an explosion

of firedamp. (2) Reentry of air into a fan. cack of Ore.—The ore between two levels which has to be worked from the lower level. Back Pressure.—The loss, expressed in pounds per square inch, due to getting the steam out of the cylinder after it has done its work.

Back Shift.—Afternoon shift.

Sack Skin (North of England).—A leather jacket for wet workings.

3ackstay.—A wrought-iron forked bar attached to the back of cars when ascending an inclined plane, which throws them off the rails if the rope or coupling breaks.

Baff Ends.—Long wooden edges for adjusting linings in sinking shafts during the operation of fixing the lining.

Baffle.—To brush out firedamp.

Bait.—Provisions.

Bajo (Mexican).—The footwall of a vein. See Respaldo.

Bal (Cornish).—A mine.

Balance.—(1) The counterpoise or weights attached to the drum of a winding engine, to assist the engine in lifting the load out of a shaft bottom and in helping it to slacken speed when the cage reaches the surface. consists often of a bunch of heavy chains suspended in a shallow shaft, the chains resting on the shaft bottom as unwound off the balance drum attached to the main shaft of the engine. (2) Scales used in chemical analysis and assaying.

Balance Bob.—A large beam or lever attached to the main rods of a Cornish pumping engine, carrying on its outer end a counterpoise.

Balance Box.—A large box placed on one end of a balance bob and filled

with old iron, rock, etc. to counterbalance the weight of pump rods.

Balance Brow.—An inclined plane in steep seams on which a platform on wheels travels and carries the cars of coal.

Balance Car.-A small weighted truck mounted upon a short inclined track,

and carrying a sheave around which the rope of an endless haulage system passes as it winds off the drum.

Balance Pit.—A pit or shaft in which a balance rises or falls.

Balanzon (Mexican).—The balance bob of a Cornish pump.

Balk.—(1) A more or less sudden thinning out of a seam of coal. (2) Irregular-shaped masses of stone intruding into a coal seam, or bulgings out of the stone roof into the seam. (3) A bar of timber supporting the roof of a mine, or for carrying any heavy load.

Balkand (Derbyshire).—Pulverulent lead ore.

Ballast.—Broken stone, gravel, sand, etc. used for keeping railroad ties steady.

Bancos (Spanish).—Horses in a vein or cross-courses.

Band.—A seam or thin stratum of stone or other refuse in a seam of coal.

Bank.—(1) The top of the shaft, or out of the shaft. (2) The surface around
the mouth of a shaft. (3) To manipulate coals, etc. on the bank.

(4) The whole or sometimes only one side or one end of a working
place underground. (5) A large heap of mineral on the surface.

BAS

Bank Chain.-A chain that includes the bank of a river or creek.

Bank Claim (Australian).—Mining right on bank of stream.
Banket.—Auriferous conglomerate of South Africa.

Bank Head.—The upper end of an inclined plane, next to the engine or drun made nearly level. Bank Right (Australian).-Right to divert water to bank claim.

Banksman.—The man in attendance at the top of the shaft, superintending the work of banking.

Bankwork.—A system of working coal in South Yorkshire.

Bank to Bank.—A shift.

Bannocking.—See Kirving.

Bano (Spanish).—Excess of mercury used in torta.

Bar.—A length of timber placed horizontally for supporting the roof. In some cases, bars of wrought iron, about 3 in. × 1 in. × 5 ft. are used.

Bar Diggings.—(1) River placers subject to overflow. (2) Auriferous claims on shallow streams.

Bargain.—Portion of mine worked by a gang on contract.

Barilla (Spanish).—Grains of native copper disseminated through ores. Baring.—See Stripping.

Barmaster (Derbyshire)-Mine manager, agent, and engineer.

Bar Mining.—The mining of river bars, usually between low and high water, although the stream is sometimes deflected and the bar worked below water level.

Barney.-A small car, used on inclined planes and slopes to push the mine car up the slope. Barney Pit.—A pit at the bottom of a slope or plane into which the barney runs to allow the mine car to pass over it.

Barra (Mexican).—(1) A bar, as of gold, silver, iron, steel, etc. (2) A certain share in a mine. The ancient Spanish laws, from time immemorial. considered a mine as divided into 24 parts, and each part was called a

Barra Viuda, or Aviada (Mexican).—These are "barras" or shares that par-ticipate in the profits, but not in the expenses, of mining concerns. Their share of the expenses is paid by the other shares. Non-assessable

Barranca (Mexican).—A ravine, a gulch. What is improperly called in the United States a canyon or cañon.

Barrel Amalgamation.—Amalgamating ores in revolving barrels.

Barrel Work.—(1) Native copper that can be hand-sorted ready for smelting. (2) Barrel amalgamation.

Barrena (Mexican).—A hand drill for opening holes in rocks for blasting

purposes. Barrenarse (Mexican).—When two mines or two workings (as a shaft or

winze, or a gallery) communicate with each other. Barren Ground.—Strata unproductive of seams of coal, etc. of a workable

thickness.

Barreno (Mexican).—(1) A drill hole for blasting purposes. In mechanics, any bored hole. (2) A communication between two mines or two workings.

Barretero (Mexican).—A miner of the first class; one that knows how to point his holes, drill, and blast, or work with a gad.

Barrier Pillar.—A solid block or rib of coal, etc., left unworked between two collieries or mines for security against accidents arising from influx of

Barrier System.—The method of working a colliery by pillar and stall, where solid ribs or barriers of coal are left in between a set or series of working

Barrow.—(1) A box with two handles at one end and a wheel at the other.

(2) Heap of waste stuff raised from a mine; a dump.

Bar Timbering.—A system of supporting a tunnel roof by long top bars while the whole lower tunnel core is taken out, leaving an open space for the masons to run up the arching. Under certain conditions, the bars are withdrawn after the masonry is completed, otherwise they are bricked in and not drawn.

Base Bullion.—Lead combined with precious metals.

Base Metal.—Metal not classed with the precious metals, gold, silver, platinum, etc., that are not easily oxidized.

Basin.—(1) A coal field having some resemblance in form to a basin. (2) The synclinal axis of a seam of coal or stratum of rock.

Basket.—A measure of weight = 2 cwt.

seque.—Crucible or furnace lining.

as (Derbyshire).—Indurated clay.

uset.—Outcrop of a lode or stratum.

stard.—A particularly hard massive rock or boulder.

atch.—An assorted parcel of ore, sometimes called doles, when divided into equal quantities.

tatea.—A shallow wooden bowl used for washing out gold, etc.

att (English).—(1) A highly bituminous shale found in the coal measures. (2) Hardened clay, but not fireclay. Same as Bend and Bind. latten.—A piece of thin board less than 12 in. in width.

latter.—The inclination of a face of masonry or of any inclined portion of a frame or metal structure. lattery.—(1) A structure built to keep coal from sliding down a chute or

(2) An embankment or platform on which miners work. A set of stamps.

Bay.—An open space for waste between two packs in a longwall working.

See Board.

Bay of Biscay Country.—(Geological).—See Crab Holes. Beach Combing.—Working the sands on a beach for gold, tin, or platinum. Beans (North of England).—All coal that will pass through about \textsty''

screen.

Benn Shot.—Copper granulated by pouring into hot water.
Bear.—A deposit of iron at the bottom of a furnace.
Bear: to Bear In.—Underholding or undermining; driving in at the top or at

the side of a working.

Bearers.—Pieces of timber 3 or 4 ft. longer than the breadth of a shaft, which are fixed into the solid rock at the sides at certain intervals apart; used as foundations for sets of timber.

Bearing.—(1) The course by a compass. (2) The span or length in the clear between the points of support of a beam, etc. (3) The points of support of a beam, shaft, axle, etc.

Bearing Door.—A door placed for the purpose of directing and regulating the amount of ventilation passing through an entire district of a mine.

Bearing In.—The depth or distance under of the undercut or holing.

Bearing-up Pulley.—A pulley wheel fixed in a frame and arranged to tighten up or take up the slack rope in endless-rope haulage. Bearing-up Stop .- A partition of brattice or plank that serves to conduct air

to a face. Beat (Cornish).—To cut away a lode.

Beataway.-Working hard ground by means of wedges and sledge hammers. Bed.—(1) The level surface of a rock upon which a curb or crib is laid. (2) A stratum of coal, ironstone, clay, etc.

Bed Claim (Australian).—A claim that includes the bed of a river or creek.

Bede.-Miners' pickax.

Bedplate.—A large plate of iron used as a foundation for an engine.

Bed Rock.—The solid rock underlying the soil, drift, or alluvial deposits. Before-Breast.—Rock or vein, which still lies ahead.

Belgian Zinc Furnace.—A furnace for the production of zinc, in which the

calcined ore is distilled in tubular retorts. Bell.—Overhanging rock or slate, of a bell-like form, disconnected from the

main roof. Belland.—A form of lead poisoning to which lead miners are subject.

Belly.—A swelling mass of ore in a lode.

Ben, Benhayl (Cornish).—Productive. The productive portion of a tin stream.

Bench.—(1) A natural terrace marking the outcrop of any stratum. (2) A stratum of coal forming a portion of the vein.

Bench Diggings.—River placers not subject to overflow.

Benching.-To break up with wedges the bottom coals when the holing is done in the middle of the seam.

Benching Up (North of England).-Working on top of coal.

Bench Mark.—A mark cut in a tree or rock whose elevation is known. Used by surveyors for reference in determining elevations.

Bench Working.—The system of working one or more seams or beds of mineral by open working or stripping, in stages or steps.

Bend (Derbyshire).—Indurated clay.

Beneficiar (Mexican).-To treat ores for the purpose of extracting the metallic contents.

Beneficio (Mexican).-Any metallurgical process.

Benheyl (Cornish).-Flowing tin stream. Bessemer Steel.—Steel made by the Bessemer process.

Beton (English).—Concrete of hydraulic cement with broken stone, brick gravel, etc.

Bevel.—The slope formed by trimming away on edge.

Bevel Gear.—A gear-wheel whose teeth are inclined to the axis of the wheel Biche.—A hollow-ended tool for recovering boring rods.

Billy Boy.—A boy who attends a Billy Playfair.

Billy Playfair.—A mechanical contrivance for weighing coal, consisting of an iron trough with a sort of hopper bottom, into which all the small coal passing through the screen is conducted and weighed off and emptied from time to time.

Bin.—A box with cover, used for tools, stones, ore, etc.

Bind, or Binder.-Indurated argillaceous shales or clay, very commonly forming the roof of a coal seam and frequently containing clay iron-stone. See Batt.

Binding.—Hiring men.
Bing (North of England).—8 cwt. of ore.
Bing Hole (Derbyshire).—An ore shoot.
Bing Ore (Derbyshire).—Lead ore in lumps.

Bing Tale (North of England).—Ore given to the miner for his labor.

Bit.—A piece of steel placed in the cutting edge of a drill or point of a pick. Blackband.—Carbonaceous ironstone in beds, mingled with coaly matter sufficient for its own calcination.

Black Batt, or Black Stone.-Black carbonaceous shale.

Black Copper.-Impure smelted copper.

Blackdamp.-Carbonic-acid gas.

Black Diamonds .- Coal.

Black Ends.—Refuse coke.

Black Flux.—Charcoal and potassium carbonate.

Black Jack.—(1) Properly speaking, dark varieties of zinc blende, but many miners apply it to any black mineral. (2) Crude black oil used to oil mine cars.

Black Lead.—Graphite.
Black Ore (English).—Partly decomposed pyrites containing copper. Black Sand.—Dark minerals found with alluvial gold.

Black Stone.—A carbonaceous shale.

Black Tin.—Dressed cassiterite; oxide of tin.

Blanch.—(1) A piece of ore found isolated in the hard rock. (2) Lead ore mixed with other minerals. Blanched Copper.—Copper alloyed with arsenic.
Blanket Strake (Australian).—Sloping tables or sluices lined with baize, for

catching gold. Blanket Tables.—Inclined planes covered with blankets, to catch the heavier

minerals passing over them.

Blast.—(1) The sudden rush of fire, gas, and dust of an explosion through the workings and roadways of a mine. (2) To cut or bring down coal, rocks, etc. by the explosion of gunpowder, dynamite, etc.

Blasting Barrel.—A small pipe used for blasting in wet or gaseous places.

Blast Pipe.—A pipe for supplying air to furnaces.

Blende.—Sulphide of zinc; sphalerite.

Blick (Germany).—Iridescence on gold and silver at end of cupeling.

Blind Coal.—Coal altered by the heat of a trap dike.

Blind Creek.—(1) A creek in which water flows only in very wet weather.

(2) (Australasian) Dry watercourse.

Blind Drift.—A horizontal passage in the mine not yet connected with the other workings.

Blind Joint.-Obscure bedding plane.

Blind Lead, or Blind Lode.—A vein having no visible outcrop.

Blind Level.—(1) An incomplete level. (2) A drainage level.

Blind Shaft, or Blind Pit. - A shaft not coming to the surface.

Bloat.—A hammer swelled at the eye.

Block Claim (Australian).—A square mining claim.

Block Coal.—Coal that breaks in large rectangular lumps.

Blocking Out.—(1) Working deep leads in blocks; somewhat like horizontal stoping. (2) (Australian) Washing gold gravel in sections.

Block Reefs.—Reefs showing frequent contractions longitudinally.

ck Tin.—Cast tin.
omary.—A forge for making wrought iron.
ssom.—The decomposed outcrop, float, surface stain, or any indicating traces of a coal bed or mineral deposit. Blossom Rock.—(1) Colored veinstone detached from an outcrop. (2) The rock detached from

a vein, but which has not been transported.

2. (2) A dam or stopping is said to

blow when gas escapes through it.

ower.—(1) A sudden emission or outburst of gas in a mine. (2) Any emission of gas from a coal seam similar to that from an ordinary gas burner. (3) A type of centrifugal fan used largely to force air into furnaces. (4) A blowdown yentilating fan.

ow Fan.—A small centrifugal fan used to force air through canvas pipes

or wooden boxes to the workmen.

lowdown Fan.—A force fan.

low In.—To commence a smelting process.

lown-Out Shot.—A shot that has blown out the tamping, but not broken the coal or rock.

low Off.—To let off excess of steam from a boiler.

Rlow Out.—(1) To finish a smelting campaign. (2) A blown-out shot. (3) The decomposed mineral exposure of a vein. Slowpipe.—An instrument for creating a blast whereby the heat of a flame

or lamp can be better utilized.

Or samp can be better utilized.

Blue Billy.—Residue of copper pyrites after roasting with salt.

Blue Cap.—The blue halo of ignited gas (firedamp and air) on the top of the flame in a safety lamp, in an explosive mixture.

Blue Fluan (Cornish).—Greenstone.

Blue John.—Fluorspar.

Blue Lead.—A blue-stained stratum of gravel of great extent and richness. Blue Metal.—A local term for shale possessing a bluish color.

Blue Peach (Cornish).—A slate-blue fine-grained schorl.

Bluestone.—(1) Sulphate of copper. (2) Lapis lazuli. (3) Basalt. (4) Maryland, a gray gnelss; in Ohio, a gray sandstone; in the District of Columbia, a mica schist; in New York, a blue-gray sandstone; in Pennsylvania, a blue-gray sandstone. (5) A popular term among stone men not sufficiently definite to be of value.

Bluff.-Blunt. Board.—A wide heading usually from 3 to 5 yd. wide.

Board-and-Pillar.—A system of working coal where the first stage of excavation is accomplished with the roof sustained by pillars of coal left between the breasts; often called Breast-and-Pillar.

Bob.-An oscillating bell-crank, or lever, through which the motion of an engine is transmitted to the pump rods in an engine or pumping pit.
There are 1 bobs, L bobs, and V bobs.

Boca or Boca Mina (Mexican).—Mouth or mine mouth. This is the name

applied to the principal or first opening of a mine, or to the one where the miners are accustomed to descend.

Bochorno (Mexican).-Excessive heat, with want of ventilation, so that the

lights go out. See Vapores.

Body.—(1) An ore body, or pocket of mineral deposit. (2) The thickness of a lubricating oil or other liquid; also the measure of that thickness expressed in the number of seconds in which a given quantity of the oil at a given temperature flows through a given aperture.

Bog Iron Ore.—Loose earthy brown hematite recently formed in swampy

Boleo (Mexican). - A dump pile for waste rock.

Boliche (Spanish).—Concentrating bowl.
Bollos (Spanish).—Triangular blocks of amalgam.
Bolsa (Spanish).—Small bunch of ore.

Bonanza.—An aggregation of rich ore in a mine.
Bond.—(1) The arrangement of blocks of stone or brickwork to form a firm structure by a judicious overlapping of each other so as to break joint. (2) An agreement for hiring men.

Bone.-Slaty coal or carbonaceous shale found in coal seams.

Bone Ash.—Burnt bones pulverized and sifted.

Bonnet,—(1) The overhead cover of a cage. (2) A cover for the gauze of a safety lamp. (3) A cap piece for an upright timber.

Bonney (Cornish) .- An isolated body of ore.

Bonze.--Undressed lead ore.

Booming.—Ground sluicing on a large scale by emptying the contents of reservoir at once on material collected below, thus removing boulders

Bord (English).—A narrow breast. Bord-and-Pillar (English).—See Pillar-and-Breast.

Bord Room.—The space excavated in driving a bord. The term is used connection with the "ridding" of the fallen stone in old bords wh driving roads across them in pillar working; thus, "ridding across t old bord room."

Bord Ways Course.—The direction at right angles to the main cleava planes. In some mining districts, it is termed "on face."

Bore.—To drill.

Bore Hole.—A hole made with a drill, auger, or other tools, in coal, rock. other material.

Borrasca (Mexican).—The reverse of bonanza. When the mine has a veil but no ore, it is said to be "en borrasca."

Bort.—Amorphous dark diamond.

Bosh.—The plane in a blast furnace where the greatest diameter is reached. Boss (English).—(1) An increase of the diameter at any part of the shaft.

(2) A person in charge of a piece of work.

Botas (Mexican).—Buckets made of an entire ox skin, to take out water.

Botryoidal.—Grape-like in appearance.

Botte Jack (English).—An appliance for lifting heavy weights.

Bottom.—(1) The landing at the bottom of the shaft or slope. (2) The lowest point of mining operations. (3) The floor, bottom rock, or stratum underlying a coal bed. (4) In alluvial, the bed rock or reef.

Bottomer, Bottomman.—The person that loads the cages at the pit bottom and gives the signal to bank.

Bottom Joint.—Joint or bedding plane, horizontal or nearly so.

Bottom Lift.—(1) The deepest column of a pump. (2) The lowest or deepest lift or level of a mine.

Bottom Pillars.-Large pillars left around the bottom of a shaft.

Bottoms.—Impure copper alloy below the matte in smelting.

Boulders.—Loose rounded masses of stone detached from the parent rock.

Bounds (Cornish).—A tract of tin ground.

Bout (Derbyshire).-Twenty-four dishes of lead ore.

Bow.—The handle of a kibble.

Bowk.—An iron barrel or tub used for hoisting rock and other débris when sinking a shaft.

Bowke (Staffordshire).-A small wooden box for hauling ironstone underground.

Bowl Metal.—The impure antimony obtained from doubling.

Bowse (Derbyshire).—Lead ore as cut from the lode.
Box.—(1) A 12' to 14' section of a sluice. (2) A mine car.

Box Bill.—Tool for recovering boring rods

Boxing.—A method of securing shafts solely by slabs and wooden pegs.

Brace.—(1) An inclined beam, bar, or strut for sustaining compression or tension. See Tie-Brace, Sway-Brace. (2) A platform at the top of a shaft on which miners stand to work the tackle. (3) (Cornish) Building at pit mouth

Brace Heads.—Wooden handles or bars for raising and rotating the rods when boring a deep hole.

Braize.—Charcoal dust.

Brake Seive .- Hand jigger.

Brances.-Iron pyrites in coal.

Branch.—Small vein shooting off from main lode.

Brashy.—Short and tender.

Brasque.-A mixture of clay and coke or charcoal used for furnace bottoms.

Brass.—(1) Iron pyrites in coal. (2) An alloy of copper and zinc. Brasses (English).—Fitting of brass in plummer blocks, etc., for diminishing

the friction of revolving journals that rest upon them. Brat.—A thin bed of coal mixed with pyrites or limestone.

Brattice.—A lining or partition.

Brattice Cloth.—Ducking or canvas used for making a brattice.

Brazzil (North of England).—Iron pyrites in coal.

Breaker.—In anthracite mining, the structure in which the coal is broken, sized, and cleaned for market. Known also as Coal Breaker,

Breaker Boy.—A boy who works in a coal breaker,

z.kstaff.—The lever for blowing a blacksmiths' bellows, or for working bore rods up and down.

cakthrough.—A narrow passage cut through a pillar connecting rooms.

cast.—(1) A stall, board, or room in which coal is mined. (2) The face or wall of a quarry is sometimes called by this name.

cast-and-Pillar.—A system of working coal by boards or rooms with pillars

of coal between them.

casting Ore.—The ore taken from the face or end of the tunnel.

east Wall (English).—A wall built to prevent the falling of a vertical face cut into the natural soil.

eccia.—A rock composed of angular fragments cemented together.

eeding Fire.—See Gob Fire.

eese. Fine slack.
eese. Small coke, probably same as braize or braise. ettis (Derbyshire).—A timber crib filled with slack.

-idge.—(1) A platform on wheels running on rails for covering the mouth of a shaft or slope. (2) A track or platform passing over an inclined haulageway and which can be raised out of the way of ascending and descending cars. (3) An air crossing.

ridle Chains.—Short chains by which a cage, car, or gunboat is attached to a winding rope; of use in case the rope pulls out of its socket.

riquets.—Fuel made of slack or culm and pressed into brick form.

roaching Bit.—A tool for reopening a bore hole that has been partially closed by swelling of the walls.

crob.—A spike to prevent timber slipping.

crob.—A spike to prevent timber slipping.

crot.—A district of coal pillars in process of removal, so called in contradistinction to the first working of a seam by bord-and-wall, or working
in the "whole." See Whole Working.

Broken Cool.—Anthracite coal that will pass through a mesh or bars 34 to 41 in., and over a mesh 21 in. square. (See page 434.)

Bronce (Mexican).—In mining, copper or iron pyrites.

Brooch (Cornish).—Mixed ores.

Brooching.—Smoothing.

Brood (Cornish).—Heavy waste from tin and copper ores.

Brow.—An underground roadway leading to a working place driven either to the rise or to the dip. Brown Coal.—Lignite. A fuel classed between peat and bituminous coal.

Brown Spar.—Dolomite containing carbonate of iron.

Brownstone.—(1) Decomposed iron pyrites. (2) Brown sandstone. Browse.—Imperfectly smelted ore mixed with cinder and clay.

Brujula (Mexican).—A surveyors (or marine) magnetic compass.

Brush.—(1) To mix air with the gas in a mine working by swinging a jacket, etc., which creates a current. (2) To "brush" the roof of an airway, is to take down some of the roof slate, to increase the height or headroom.

Bryle (Cornish).—Traces of a vein in loose matter.

Bucket.—(1) An iron or wooden receptacle for hoisting ore, or for raising rock in shaft sinking.
 (2) The top valve or clack of a pump.
 Bucket Pump.—A lifting pump, consisting of buckets fastened to an endless

belt or chain.

Bucket Sword.—A wrought-iron rod to which the pump bucket is attached. Bucket Tree.—The pipe between the working barrel and the wind bore.

Bucking.—Breaking down ore with a very broad hammer, ready for jigging. Bucking Hammer.—An iron disk, provided with a handle, used for breaking up minerals by hand.

Buck Quartz.—Hard non-auriferous quartz.

Buck Staff.—Uprights for bracing reverberatory furnaces together.
Buckwheat.—Anthracite coal that will pass through a mesh \(\frac{1}{2}\) in. and over a mesh ‡ in.

Buddle.—An inclined table, circular or oblong, on which ore is concentrated. Buddling .- Washing.

Buggy.-A small mine car.

Bug Hole.—A small cavity usually lined with crystals.

Building.—A built-up block or pillar of stone or coal to support the roof. Buitron (Spanish) .- A silver furnace of peculiar form.

Bulkhead.—(1) A tight partition or stopping. (2) The end of a flume carrying water for hydraulicking.

Bulldog .- A refractory furnace lining of calcined mill cinder, contains iron and silica.

Bull Engine.-A single, direct-acting pumping engine, the pump rods for

ing a continuation of the piston rod.

Buller Shot.—A second shot put in close to, and to do the work not done by a blown-out shot, loose powder being used.

Bull.—An iron rod used in ramming clay to line a shot hole.
Bulling.—Lining a shot hole with clay.
Bullion.—Uncoined gold and silver.

Bull Pump.—A single-acting pumping engine in which the steam cylinder in placed over the shaft or slope and the pump rods are attached directly to the piston rod. The steam enters below the piston and raises the pumping th rods; the water is pumped on the down stroke by the weight of the rod Bull Pup.-A worthless claim.

Bull Wheel.—A wheel on which the rope carrying the boring rod is coiled when boring by steam machinery.

Bully.—A miners' hammer.

Bumping Table.—A concentrating table with a jolting motion.

Bunch.-A small rich deposit of ore.

Bunding.—A staging in a level for carrying débris. Bunkers.-Steam coal consumed on board ship.

Bunney.—A nest of ore not lying in a regular vein. Buntons.—Timbers placed horizontally across a shaft or slope to carry the cage guides, pump rods, column pipe, etc.; also, to strengthen the shaft timbering.

Burden.—(1) Earth overlying a bed of useful mineral. (2) The proportion of ore and flux to fuel in the charge of a blast furnace.

Burr.—Solid rock.

Burrow.—Refuse heap.

Buscones (Spanish).—Prospectors, fossickers, tribute workers.

Bush.—To line a circular hole with a ring of metal, to prevent the hole from

wearing out.

Butt.—(1) Coal surface exposed at right angles to the face; the "ends" of the coal. (2) The butt of a slate quarry is where the overlying rock comes in contact with an inclined stratum of slate rock.

Butt Entry.—A gallery driven at right angles with the butt joint (see page 285). Butterfly Valve.—A circular valve that revolves on an axis passing through its center.

Butt Heading.—See Butt Entry.

Button.—The globule of metal, the result of an assay.

Button Balance.—A small very delicate balance used for weighing assay

Butty.—A partner in a contract for driving or mining; a comrade, crony. Sometimes called "Buddy."

By Level.—A side level driven for some unusual but necessary purpose.

Cab.—The side parts of a lode, nearest the walls, which are generally hard

and deficient of ore. Caballo (Mexican).-A "horse" or mass of barren rock in a vein.

Cabezuela (Spanish).—Rich gold and silver concentrates.

Cabin.—(1) A miner's house. (2) A small room in the mine for the use of the officials.

Cable Drilling.-Rope drilling.

Cage.—A platform on which mine cars are raised to the surface.

Cage Guides.—Vertical rods of pine, iron, or steel, or wire rope, fixed in a shaft, between which cages run, and whereby they are prevented from striking one another, or against any portion of the shaft.

Cager.—The person that puts the cars on the cage at the bottom of the shaft. Cage Seat.—Scaffolding, sometimes fitted with strong springs, to take off the

shock, and on which the cage drops when reaching the pit bottom.

Cage Sheets.—Short props or catches on which cages stand during caging or changing cars.

Caking Coal.—Coal that agglomerates on the grate. Cal.—Wolfram.

Cala (Spanish).—Prospecting pit.

Calcareous.—Containing lime.

Calcine.—To heat a substance; not sufficiently to melt it, but enough to drive off the volatile contents.

calcining Furnace.-A furnace used for roasting ore in order to drive off certain impurities.

Caliche (Spanish).—Feldspar.

California Pump.—A rude pump made of a wooden box through which an endless belt with floats circulates; used for pumping water from shallow ground.

Callys (Cornish).—Stratified rocks traversed by lodes.

Cam.—(1) A curved arm attached to a revolving shaft for raising stamps.

(2) Carbonate of lime and fluorspar, found on the joints of lodes. Camino (Mexican).—Any gallery, winze, or shaft, inside of a mine used for

general transit.

Canada (Mexican).—See Barranca.

Canada (Mexican).—See Barranca.

Canah, or Caunche.—(1) A thickness of stone required to be removed to make height or to improve the gradient of a road. If above a seam, it is termed a "top canch"; if below, a "bottom canch." (2) A trend with sloping sides and very narrow bottom.

Cancha (Spanish).—Space for drying slimes.

Cand (Cornish).—Fluorspar.

Cank (Derbyshire).-Whinstone.

Canker.—The ocherous sediment in coal-pit waters. Cannel Coal.—See Classification of Coals (page 170).

Cañon (Mexican).—A level, drift, or gallery within a mine. Cañon de Guia.-A drift along the vein.

Cants (English).—The pieces forming the ends of buckets of a waterwheel. Cap.—(1) A piece of plank placed on top of a prop. See, also, Collar. (2) The pale bluish elongation of the flame of a lamp caused by the presence

Capellina (Mexican).—An old-style retort for retorting silver amalgam.

Caple (Cornish).—Hard rock lining tin lodes.

Cap Rock.—The upper rock that covers the bed rock. Capstan.—A vertical axle used for heavy hoisting, and worked by horizontal arms or bars.

Captain.-Cornish name for manager or boss of a mine.

Car.—Any car used for the conveyance of coal along the gangways or haulage roads of a mine.

Carat.—A weight nearly equal to 4 grains.

Carbon.-A combustible elementary substance forming the largest component part of coal.

Carbona.—(1) A rich bunch of ore in the country rock connected with the lode by a mere thread of mineral. (2) (Cornish) An irregular deposit

Carbonaceous.—Coaly, containing carbon or coal. Carbonate.—Carbonic acid combined with a base.

Carbonates.—Lead ore. The oxide and carbonic-acid compounds of lead; also applied to lead sulphate.

Carboniferous.—Containing or carrying coal.

Carga (Mexican).—A charge. A mule load, generally of 300 pounds, but variable in different parts of Mexico. Carriage.—See Cage and Slope Cage.

Cartridge.-Paper or waterproof cylindrical case filled with gunpowder, forming the charge for blasting. Cascajo (Mexican).—Gravel.

Case.—A fissure admitting water into a mine.
Case-Harden.—To convert the outer surface of wrought iron into steel by heating it while in contact with charcoal.
Casing.—Tubing inserted in a bore hole to keep out water or to protect the

sides from collapsing.

Cast Iron.—Pig iron that contains carbon (up to 5%), silicon, sulphur, phos-

phorus, etc.

Cata (Spanish).—A mine denounced but not worked. Catches.—(1) Iron levers or props at the top and bottom of a shaft. (2) Stops fitted on a cage to prevent cars from running off.

Catch Pit.—A reservoir for saving tailings from reduction works. Cauf (North of England).—A coal bucket or basket.

Cauldron Bottoms. - The fossil remains or the "casts" of the trunks of sigillaria that have remained vertical above or below the seam.

Caulk.—To fill seams or joints with something to prevent leaking.

Caunter, or Caunter Lode (Cornish).—A vein running obliquely across the regular veins of the district.

Cave, or Cave In .- A caving-in of the roof strata of a mine, sometimes extending to the surface.

Cavils.—Lots drawn by the hewers each quarter year to determine their working places.

Cawk.-Baryta sulphate.

Cazeador (Spanish).—Amalgamator.

Cazo (Mexican).—A vessel for hot amalgamation. Any large copper or iron

Cebar (Mexican).—(1) To melt rich ores, or lead bullion, etc. in a smelting furnace. (2) To add small quantities of material, from time to time, to the melted mass within a furnace. (3) Generally, to feed any kind of

metallurgical machinery or process.

Cement.—(1) Auriferous gravel consolidated together. (2) A finely divided metal obtained by precipitation. (3) A binding material.

Cementation.—The process of converting wrought iron into steel by heating it in contact with charcoal, or of treating cast iron in a bed of hematite ore.

Cendrada (Mexican).—The cupel bottom of a furnace.

Cendradilla (Mexican).—A small reverberatory furnace for smelting rich silver ores in a rough way. Also called Galeme.

Center.—A temporary support, serving at the same time as a guide to the masons, placed under an arch during the progress of its construction.

Centrifugal Force.—A force drawing away from the center.

Centripetal Force.—A force drawing toward the center.

CH4.-Marsh gas (see page 348).

Chain.—A measure 66 or 100 ft. long, divided into 100 links.

Chain-Brow Way.—An underground inclined plane worked on the endlesschain system of haulage.

Chain Pillar.—A pillar left to protect the gangway and air-course, and run-

ning parallel to these passages.

Chain Road.—An underground wagonway worked on the endless-chain system of haulage.

Chair.—Sometimes applied to keeps. Chamber.—See Breast.

Charco (Mexican).-A pool of water.

Charge.—(1) The amount of powder or other explosive used in one blast or shot. (2) The amount of flux used in assaying. (3) The material fed

into a furnace at one time.

Charquear (Mexican).—To dip out water from pools within the mine, throwing it into gutters or pipes that will conduct it to the shaft.

Chats.—(1) The gravel-like tailings derived from the concentration of ores. (2) A low-grade ore, often too poor to handle; the refuse from concentration works. (3) (North of England) Small pieces of stone with ore.

Check-Battery.—A battery to close the lower part of a chute, acting as a

check to the flow of coal and as an air stopping.

Checker Coal.—Anthracite coal that seems to be made up of rectangular

Check-Weighman.—A man appointed and paid by the miners to check the weighing of the coal at the surface.

Chert.—A silicious rock, often the gangue of lead and zinc. Chestnut Coal.—Anthracite coal that will pass through a mesh 11 in. square

and over a mesh # in. square (see page 434).

Chiffon (Mexican).—A narrow drift directed obliquely downwards. Any pipe from which issues water or air under pressure, or at high velocity.

Chile Bars.—Bars of impure copper, weighing about 200 lb., imported from

Chile, corresponding to the Welsh blister copper, containing 98% Cu.

Chilian Mill.—A roller mill for crushing ore.

Chill Hardening.—Giving a greater hardness to the outside of cast iron by pouring it into iron molds, which causes the skin of the casting to cool rapidly

Chimney.—(1) An ore shoot. (2) A furnace or air stack.

Chinese Pump.—Like a California pump, but made entirely of wood. Chock.—A square pillar for supporting the roof, constructed of prop timber laid up in alternate cross-layers, in log-cabin style, the center being filled with waste.

Chokedamp.—See Blackdamp.
Churn Drill.—A long iron bar with a cutting end of steel, used in quarrying, and worked by raising and letting it fall. When worked by blows of a hammer or sledge, it is called a "jumper."
Chute (also spelled Shute).—(1) A narrow inclined passage in a mine, down which coal or ore is either pushed or slides by gravity. (2) The load-

ing chute of a tipple.

Chuza (Spanish).—A catch basin for mercury.

Cielo (Mexican.)—A ceiling. Trabajar de Cie Trabajar de Cielo.—Overhead stoping.

Cinnabar.—Mercury and sulphur.

Clack.—A valve that is opened and closed by the force of the water.

Clack Door .- The opening into the valve chamber to facilitate repairs and renewals without unseating the pump or breaking the connections.

Clack Piece.—The casting forming the valve chamber. Clack Seal.—The receptacle for the valve to rest on.

Claggy (North of England).—When coal is tightly joined to the roof.

Claim.—A portion of ground staked out and held by virtue of a miner's

Clanny.—A type of safety lamp invented by Dr. Clanny.

Clastic.—Constituted of rocks or minerals that are fragments derived from other rocks.

Clay Course.—A clay seam or gouge found at the sides of some veins.

Claying Bar.—For molding clay in a wet bore hole.

Clay Band.—Argillaceous iron ore; common in many coal measures.

Clean-Up.—Collecting the product of a period of work with battery or sluice. Clearance.—(1) The distance between the piston at the end of its stroke and the end of the cylinder. (2) The volume or entire space filled with steam at end of a stroke including the space between piston and cylinder head, and the steam ducts to the valve seat.

Cleat.—(1) Vertical cleavage of coal seams, irrespective of dip or strike. (2)
A small piece of wood nailed to two planks to keep them together, or
nailed to any structure to make a support for something else.

Cleavage.—The property of splitting more readily in some directions than in

Clinometer.—An instrument used to measure the angle of dip.

Clod.—Soft and tough shale or slate forming the roof or floor of a coal seam. Closed Season.-When placers cannot be worked.

Clunch (English).-Under clay, fireclay

Clutch.—An arrangement at the end of separate shafts by means of which they catch into each other, so that both can revolve together.

Coal Breaker. - See Breaker.

Coal Cutter.—A machine for holing or undercutting coal.

Coal Dust.—Very finely powdered coal suspended in the airways of a mine. Coal Measures .- Strata of coal with the attendant rocks.

Coal Pipes (North of England).—Very thin irregular coal beds.

Coal Road.—An underground roadway or heading in coal.

Coal Smut.-See Blossom.

Coaly Rashings.—Soft dark shale, in small pieces, containing much carbonaceous matter.

Coarse (Coose).—When lode stuff is not rich, the ore being only thinly disseminated throughout it.

Coarse Metal.-In copper smelting, the compound containing the copper concentrated in it after the first smelting to get rid of the bulk of the gangue in the ore.

Coaster. -One that picks ore from the dump.

Cob (Cornish).—To break up ore for sorting

Cobbing Hammer.—A short double-ended hammer for breaking minerals to Cobre.—Cuban copper ores.

Cockerneg, or Cockers.-Timber used to hold coal face while it is being undercut.

Cockle (Cornish).-Black tourmaline, often mistaken for tin.

Cod (North of England).—The bearing of an axle.

Cofer (Derbyshire).—To calk a shaft by ramming clay behind the lining.

Coffer. - Mortar box of a battery

Coffer Dam.—An enclosure built in the water, and then pumped dry, so as to permit masonry or other work to be carried on inside of it. Coffin (Cornish).—An old pit.

Cog.—A chock.

Cohete (Mexican).—A rocket; applied to a blast within a mine or outside.

Coll Drag.—A tool for picking pebbles, etc. from drill holes.

Coke.—The fixed carbon and ash of coal sintered together.

Colas (Spanish).—Tailings from a stamp mill or any wet process.

Collar.—(1) A flat ring surrounding anything closely. (2) Collar of a shaft is the first wood frame of a shaft. (3) The bar or crosspiece of a framing in entry timbering.

Colliery.—The whole plant, including the mine and all adjuncts.

(Figlish)—Talegraphic messages sent from si

Colliery Warnings (English).—Telegraphic messages sent from signal-service stations to the principal colliery centers to warn managers of mines when sudden falls of the barometer occur.

Colores (Mexican).—Decomposed ores stained with iron. Colores (Mexican).—Metal-stained ground or rocks.

Colrake.—A shovel for stirring lead ores while washing.

Color.—Minute traces or individual specks of gold.

Column, or Column Pipe.—The pipe conveying the drainage water from the mine to the surface.

Comer (Mexican).—To eat. Comerse los Pilares.—To take out the last vestiges of mineral from the sides and rock pillars of a mine.

Conchoidal.—Shell-like, such as the curved fracture of flint.

Concrete.—Artificial stone, formed by mixing broken stone, gravel, etc. with lime, cement, tar, or other binder. When hydraulic cement is used instead of lime, the mixture is called beton (English).

Concretion.—A cemented aggregation of one or more kinds of minerals

around a nucleus.

Conduit.—(1) A covered waterway. (2) An airway. Conduit Hole.-A flat hole drilled for blasting up a thin piece in the bottom

of a level.

Conductors (English).—See Guides.
Conformable.—Strata are conformable when they lie one over the other with

the same dip.

Conglomerate.—The rock formation underlying the Coal Measures; a rock containing or consisting of pebbles, or of fragments of other rocks cemented together; English Pudding Rock or milistone grit.

Conical Drum.—The rope roll or drum of a winding engine, constructed in the form of two truncated cones placed back to back, the outer ends

being usually the smaller in diameter.

Consumido (Mexican).—The amount of mercury that disappears by chemical combination during the treatment of ore by any amalgamation process.

Contact.—Union of different formations.

Contact Load or Vein.-A vein lying between two differently constituted

Contour.—(1) The line that bounds the figure of an object. (2) In surveying, a contour line is a line every point of which is at an equal elevation. Contramina (Mexican).—Countermine. Any communication between two or more mines. Also, a tunnel communicating with a shaft.

Cope (Derbyshire).—Lead mining on contract.
Cope, or Coup.—An exchange of working places between hewers.

Copelilla (Spanish).—Zinc-blende. Copella (Spanish).—Dry amalgam.

Copper Plate.—A sheet of copper that, when coated with mercury, is used in amalgamation.

Corbond.—An irregular mass from a lode.

Cord.—A cord weighs about 8 tons.

Cores.—Cylinder-shaped pieces of rock produced by the diamond-drill system. of boring.

Corf.—A mine wagon or tub.

Cornish Pumps.—A single-acting pump, in which the motion is transmitted through a walking beam; in other respects similar to a Bull Pump. Coro-Coro (South American).—Grains of native copper mixed with pyrite,

chalcopyrite, mispickel, etc.

Cortar Pillar (Mexican).—To form a rock support or pillar within a mine. at the opening of a cross-cut or elsewhere.

Cortar Sogas (Mexican).-Literally, to cut the ropes. To abandon the mine, taking away everything useful or movable.

Corve.-A mining wagon or tub.

Costean (Cornish).—To prospect a lode by sinking pits on its supposed course.

Cos

Costeaning.—Trenching for a lode. Cost Book (Cornish).—Mining accounts.

Cotton Rock.—(1) Decomposed chert. (2) A variety of earthy limestone. Coulee.—(1) A solified stream or sheet of lava extending down a volcano,

often forming a ridge or spur. (2) A deep gulch or water channel,

usually dry. Counter.—(1) A cross-vein. (2) (English) An apparatus for recording the number of strokes made by the Cornish pumping engine. (3) A secondary haulageway in a coal mine.

Counterchute.—A chute down which coal is dumped to a lower level or gangway.

Countergangway.-A level or gangway driven at a higher level than the main one.

Country.—The formation traversed by a lode.

Country Rock.—The main rock of the region through which the veins cut, or that surrounding the veins.

Course. - The direction of a line in regard to the points of compass.

Coursing or Coursing the Air.—Conducting it through the different portions of a mine by means of doors, stoppings, and brattices.

Cow.-A self-acting brake. Coyoting.-Irregular mining by small pits.

Crab.—A variety of windlass or capstan consisting of a short shaft or axle, either horizontal or vertical, which serves as a rope drum for raising weights; it may be worked by a winch or handspikes.

Crab Holes.—Holes often met with in the bed rock of alluvial. Also depressions on the surface owing to unequal disintegration of the underlying

Cradle.-A box with a sieve mounted on rockers for washing auriferous alluvial.

Cradle Dump.—A rocking tipple for dumping cars. See Dump.
Cramp (English).—(1) A short bar of metal having its two ends bent downwards at right angles for insertion into two adjoining pieces of stone, wood, etc. to hold them together. (2) A pillar left for support in a mine.

Cranch.—Part of a vein left by previous workers.

Crane (English).—A hoisting machine consisting of a revolving vertical post or stalk, a projecting jib, and a stay for sustaining the outer end of the jib; these do not change their relative positions as they do in a derrick. There is also a rope drum with winding rope, etc. Creaze (Cornish).—(1) Tin ore collected in the middle of the buddle. (2) The

middle of a buddle.

Creep.—The gradual upheaval of the floor or sagging of the roof of mine workings due to the weighting action of the roof and a tender floor. Creston (Mexican).—The outcrop or apex of a vein or mineral deposit. Crevice. - A fissure.

Crevicing.—Picking out the gold caught in cracks and crevices in the rocks

over which it has been washed.

Criadero (Mexican).—(1) A mineral deposit of irregular form, not vein-like. (2) A chamber in a vein filled with ore of more or less richness. (3) Any mineral deposit. This latter is the more modern sense, and the word is so used in the mining laws at present in force in Mexico.

Crib.—(1) A structure composed of horizontal timbers laid on one another, or a framework built like a log cabin. See Chock. (2) A miner's lunch-

eon. (3) See Curb.

Cribbing.-Close timbering, as the lining of a shaft, or the construction of cribs of timber, or timber and earth or rock to support a roof.

Cribble.—A sieve.

Crisol (Mexican).—A crucible of any kind. Crop.—See Outcrop.

Crop Fall .- A caving in of the surface at or near the outcrop of a bed of coal. cropping Coal.—The leaving of a small thickness of coal at the bottom of the seam in a working place, usually in order to keep back water. The coal so left is termed "Cropper Coal."

Croppings.—Portions of a vein as seen exposed at the surface.

Cropping Out.—Appearing at the surface; outcropping.

Cross-Course.—A vein lying more or less at right angles to the regular vein of the district.

Crosscut.-(1) A tunnel driven through or across the measures from one seam to another. (2) A small passageway driven at right angles to the main gangway to connect it with a parallel gangway or air-course.

Crosses and Holes (Derbyshire).—Made in the ground by the discoverer of a

lode to temporarily secure possession.

Cross-Heading.—A passage driven for ventilation from the airway to the gangway, or from one breast through the pillar to the adjoining working.

Cross-Heading, or Cross-Gateway.—A road kept through goaf and cutting off the gateways at right angles or diagonally.

Cross-Hole.—See Crosscut (2).

Cross-Latches.—See Latches.

Cross-Spur.-A vein of quartz that crosses the reef.

Cross-Vein.—An intersecting vein.

Crouan (Cornish).—Granite.

Crowbar.—A strong iron bar with a slightly curved and flattened end. Crowfoot.—A tool for drawing broken boring rods.

Crown Tree.—A piece of timber set on props to support the roof.

Crucero (Mexican).—A crosscut for ventilation to get around a horse, or to prospect for the vein. Crucible.—(1) The bottom of a cupola furnace in which the molten materials

collect. (2) Pots for smelting assays in.

Crush .- See Squeeze, Thrust.

Crusher .- A machine used for crushing ores and rock.

Crushing.—Reduction of mineral in size by machinery.

Crystal.—A solid of definite geometrical form, which mineral (or sometimes organic) matter has assumed. Culm.—Anthracite-coal dirt.

Culm Bank, or Culm Dump.—Heaps of culm now generally kept separate from the rock and slate dumps.

Cuña (Mexican).—Literally, a wedge. A short drill or picker generally known in the United States as a "gad."

Cupel.—A cup made of bone ash for absorbing litharge.

Curb.—(1) A timber frame intended as a support or foundation for the lining of a shaft. (2) The heavy frame or sill at the top of a shaft. Curbing.-The wooden lining of a shaft.

Cut.—(1) To strike or reach a vein. (2) To excavate in the side of a hill. Cutter.—A term employed in speaking of any coal-cutting or rock-cutting. machines; the men operating them, or the men engaged in underholing by pick or drill. Cutting Down.—To cut down a shaft is to increase its sectional area.

Dam.—A timber bulkhead, or a masonry or brick stopping built to prevent the water in old workings from flooding other workings, or to confine the water in a mine flooded to drown out a mine fire.

Damp.—Mine gases and gaseous mixtures are called damps. See also Afterdamp, Blackdamp, Firedamp, Stinkdamp.

Dan (North of England).—A truck without wheels.

Danger Board.—See Firéboard.

Dant (North of England).—Soft inferior coal.

Datum Water Level.-The level at which water is first struck in a shaft sunk on a reef or gutter.

Davy.—A safety lamp invented by Sir Humphrey Davy.

Day.—Light seen at the top of a shaft.

Day Fall.—See Crop Fall.

Day Shift.—The relay of men working in the daytime.

Dead.—The air of a mine is said to be dead or heavy when it contains carbonic-acid gas, or when the ventilation is sluggish.

Dead.—(1) Unproductive. (2) Unventilated.

Dead Men's Graves (Australian).—Grave-like mounds in the basalt under-

lying auriferous gravels.

Dead Quartz.—Quartz carrying no mineral. Dead Riches.—Lead carrying much bullion.

Dead Roast.—To completely drive off all volatile substances.

Deads.-Waste or rubbish from a mine.

Dead Work.—Exploratory or prospecting work that is not directly productive. Brushing roof, lifting bottom, cleaning up falls, blowing rock, etc. Dean (Cornish).—The end of a level.

bris.—Fragments from any kind of disintegration.

- Deep (English).—"To the deep," toward the lower portion of a mine; hence, the lower workings.
- Delta.—A triangularly shaped piece of alluvial land at the mouth of the river.
- Demasia (Mexican).—A piece of unoccupied ground between two mining concessions.

Denudation.—The laying bare by water or other agency.

Denuncio (Mexican).—Denouncement. The act of applying for a mining concession under the old mining laws.

Deposit.-(1) Irregular ore bodies not veins. (2) A bed or any sedimentary formation.

Deputy (English).—(1) A man who fixes and withdraws the timber supporting the roof of a mine, and attends to the safety of the roof and sides, builds stoppings, puts up bratticing, and looks after the safety of the hewers, etc. (2) An underground official who sees to the general safety of a certain number of stalls or of a district, but does not set the timber himself, although he has to see that it is properly and suffi-

ciently done. (3) (American) A deputy sheriff.

Derrick.—(1) A crane in which the rope or chain forming the stay can be let out or hauled in at pleasure, thus altering the inclination of the jib. (2) The structure erected to sink a drill hole and the framework above shafts are sometimes called by this name.

Derrumbe, or Derrumbamineto (Mexican).—The caving in of the whole or a portion of a mine.

Desaguador (Spanish).—A water pipe or drain.
Desague (Mexican).—Drainage of a mine by any means.

Descargar (Mexican).-Literally, "to unload." Descargar un Horno.-To tear down a furnace.

Descubridora (Mexican).—The first mine opened in a new district or on a new mineral deposit.

Desccho (Spanish).—Foul red mercury.

Desfrute (Mexican).—Taking out ore. Obras de Desfrute.—Stopes, etc.

Desmontar (Mexican).—Literally, to clear away underbrush. In mining, to take away useless and barren rocks; to remove rubbish.

Desmontes (Spanish).—Poor ores.
Despensa (Mexican).—(1) A pantry or storeroom. (2) A secure room to lock up rich ore.

Despoblado (Spanish).—Ore with much gangue.
Despoblar (Mexican).—To suspend work in a mine.
Dessue (Cornish).—To cut away the ground beside a thin vein so as to

remove the latter whole. Destajo (Mexican).—(1) A contract to do any kind of work in or about a mine or elsewhere for a fixed price. (2) Piece work, as distinguished

from time work. Destajero .- A contractor for piece work.

Detaching Hook.-A self-acting mechanical contrivance for setting free a winding rope from a cage when the latter is raised beyond a certain point in the head-gear; the rope being released, the cage remains suspended in the frame.

Devil's Dicc.—Cubes of limonite, pseudomorphs after pyrites.
Diagonal Joints.—Joints diagonal to the strike of the cleavage.
Dial (English).—An instrument similar to a surveyor's compass, with vernier attached.

Dialing.-Surveying.

Die.—The bottom iron block of a battery, or grinding pan on which the shoe acts.

Digging.—Mining operations in coal or other minerals.

Diggings.—Where gold and other minerals are dug out from shallow alluvials.

Dike.—See also Dyke.
Dillies, or Ginneys.—Short self-acting inclines where one or two tubs at a time are run.

Diffueing (Cornish).—Dressing tin slimes in a fine sieve.

Dip.—(1) To slope downwards. (2) The inclination of strata with a horizontal plane. (3) The lower workings of a mine.

Dip Joint.—Vertical joints about parallel to the direction of the cleavage dip.

Dip Joint.—A world worth weter and the direction of the cleavage dip.

Dippa (Cornish).—A small catch-water pit.

Dipping Needle.—A magnetic needle suspended in a vertical plane; for locating iron deposits.

Dirt Fault.-A confusion in a seam of coal, the top and bottom of the sear

Dirt ratue.—A communon in a seam of coal, the top and bottom of the seab being well defined, but the body of the vein being soft and dirty. Dish (Cornish).—An ore measure; in lead mines, a trough 28 in. long, 4 in deep, and 6 in. broad; sometimes 1 gallon, sometimes 14 to 16 pints. Distintegration.—Separation by mechanical means, not by decomposition. Ditch.—(1) The drainage gutter in a mine. (2) A drainage gutter on the surface. (3) An open conveyor of water for hydraulic or irrigation purposes.

Divide.—The top of a ridge, hill, or mountain.

Dividing State.—A stratum of slate separating two benches of coal.

Divining, or Dowsing, Rod.-A small forked hazel twig that, when held loosely in the hands, is supposed to dip downwards when passing over water or metallic minerals.

Dizzue (Cornish).—See Dessue.

Dog.-(1) An iron bar, spiked at the ends, with which timbers are held together or steadied. (2) A short heavy iron bar, used as a drag behind a car or trip of cars when ascending a slope to prevent their running back down the slope in case of accident. See Drag.

Dog Hole .- A little opening from one place in a mine to another, smaller

than a breakthrough.

Dog Iron.—A short bar of iron with both ends pointed and bent down so as to hold together two pieces of wood into which the points are driven. Or one end may be bent down and pointed, while the other is formed into an eye, so that if the point be driven into a log, the other end may be used to haul on.

Doles.—Small piles of assorted or concentrated ore.

Dolly.—(1) A machine for breaking up minerals, being a rough pestle and mortar, the former being attached to a spring pole by a rope. (2) A tool used to sharpen drills.

Tub (Cornish).—A tub in which ore is washed, being agitated by a

dolly or perforated boards.

Donk (North of England).—Soft mineral found in cross-veins.

Donkey Engine (English).-(1) A small steam engine attached to a large one, and fed from the same boiler; used for pumping water into the boiler. (2) A small steam engine. Door Piece (English).—The portion of a lift of pumps in which the clack or

valve is situated.

Doors.—Wooden doors in underground roads or airways to deflect the aircurrent. Door Tender.—A boy whose duty it is to open and close a mine door before

and after the passage of a train of mine cars.

The material that absorbs

Dope.—An absorbent for holding a thick liquid.

the nitroglycerine in explosives.

Double Shift.—When there are two sets of men at work, one set relieving the other.

Double Tape Fuse.—Fuse of superior quality, or having a heavier and stronger

covering.

Double Timber.—Two props with a bar placed across the tops of them to support the roof and sides.

Downcast.—The opening through which the fresh air is drawn or forced into the mine; the intake.

Dradge (Cornish).—(1) Inferior ore separated from the prill. (2) Pulverized

refuse. Draftage.—A deduction made from the gross weight of ore when transported.

to allow for loss.

Drag.—(1) The frictional resistance offered to a current of air in a mine.
(2) See Dog.

Draw.—(1) To "draw" the pillars; robbing the pillars after the breasts are exhausted. (2) An effect of creep upon the pillars of a mine. Draw a Charge.—To take a charge from a furnace.

Drawlift.—A pump that receives its water by suction and will not force it above its head.

Draw-Hole.—An aperture in a battery through which the coal is drawn.

Drawing an Entry.—Removing the last of the coal from an entry. Drawn.—The condition in which an entry or room is left after all the coal has been removed. See Robbed.

Dresser (Staffordshire) .- A large coal pick.

ressing.—Preparing poor or mixed ores mechanically for metallurgical operations.

pressing Floors.—The floors or places where ores are dressed.

rift.—(1) A horizontal passage underground. A drift follows the vein, as distinguished from a crosscut, which intersects it, or a level or gallery, which may do either. (2) In coal mining, a gangway above water level, driven from the surface in the seam. (3) Unstratified diluvium.

prifting.—Winning pay dirt from the ground by means of drives.

Prill.—An instrument used in boring holes.

Prive (Drift). A horizontal passage in a lode.
Prive.—To cut an opening through strata.
Priving.—Excavating horizontal passages, in contradistinction to sinking or raising.

Driving on Line.—Keeping a heading or breast accurately on a given course

by means of a compass or transit.

Dropper.—(1) A spur dropping into the lode. (2) A feeder. (3) A branch leaving the vein on the footwall side. (4) Water dropping from the roof. (3) A branch Drop Shaft.—A monkey shaft down which earth and other matter are lowered by means of a drop (i. e., a kind of pulley with break attached); the empty bucket is brought up as the full one is lowered.

Druggon (Staffordshire).—A vessel for carrying fresh water into a mine.

Drum.—The cylinder or pulley on which the winding ropes are coiled or wound.

Drum Rings.—Cast-iron rings with projections to which are bolted the laggings forming the surface for the ropes to lap on.

Drummy.—Sounding loose, open, shaky, or dangerous when tested. Druse.—A hollow cavity lined with small crystals.

Dry Amalgamation.—Treating ores with hot, dry mercury.

Dry Diggings.—Placers never subject to overflow.

Dry Ore.—Argentiferous ores that do not contain enough lead for smelting purposes.

Duck Machine.—An arrangement of two boxes, one working within the

other, for forcing air into mines.

Duelas (Mexican).—Staves of a barrel or cask, etc.

Dumb'd.—Choked, of a sieve or grating.

Dumb Drift.—A short tunnel or passage connecting the main return airways of a mine with the upcast shaft some distance above the furnace, in order to prevent the return air laden with mine gases from passing through or over the ventilating furnace.

Dump.—(1) A pile or heap of ore, coal, culm, slate, or rock. (2) The tipple by which the cars are dumped. (3) To unload a car by tipping it up. (4) The pile of mullock as discharged from a mine.

Dumper.—A car so constructed that the body may be revolved to dump the material in front or on either side of the track.

Durn (Cornish).—A timber frame. Durr (German).—Barren ground.

Dust. - See Coal Dust.

Dust Gold.—Pieces under 2 to 3 dwt.

Duty.—The unit of measure of the work of a pumping engine expressed in foot-pounds of work obtained from a bushel, or 100 lb., or other unit of fuel.

Dyke, or Dike.-(1) A wall of igneous rock passing through strata, with or without accompanying dislocation of the strata. (2) A fissure filled with igneous matter. (3) Barren rock.

Dzhu (Cornish).—See Dessue.

Ear.—The inlet or intake of a fan.

Echadero (Mexican).—A level place near a mine where ore is cleaned, piled, weighed, and loaded on mules or other conveyance. Also called patio of

Echado (Mexican).-The dip of the vein.

Edge Coals (English).—Highly inclined seams of coal, or those having a dip greater than 30°.

Efflorescence.—An incrustation by a secondary mineral, due to loss of water of crystallization.

Efydd (Wales).—Copper.

Egg Cool.—Anthracite coal that will pass through a 27" square mesh and over a 2" square mesh (see page 434).

Elbow.—A sharp bend, as in a lode or pipe.

Electric Blast.—Instantaneous blasting of rock by means of electricity.

Elevator Pump.—An endless band with buckets attached, running over two drums for draining shallow ground.

Elvan.-A Cornish name applied to most dike rocks of that county, irrespective of the mineral constitution, but in the present day restricted to quartz porphyries.

Emborrascarse (Mexican).—To go barren by the vein terminating or pinching out, etc.

Empties.—Empty mine or railroad cars. Encino (Mexican).-Live oak.

End Joint (End Cleat).—A joint or cleat in a seam about at right angles to the principal or face cleats.

Endless Chain.—A system of haulage or pumping by the moving of an endless chain.

Endless Rope.—A system of haulage same as endless chain, except that a wire rope is used instead of chain.

End, or End-On.—Working a seam of coal at right angles to the principal or face cleats.

Engine Plane.—An incline up which loaded cars are drawn by a rope operated by an engine located at the top or bottom of the incline. The empty cars descend by gravity, pulling the rope after them.

Engineer.—(1) One who has charge of the surveying or machinery about a mine. (2) One who runs an engine.

Ensayes (Mexican).—Assays.
Entibar (Mexican).—To timber a mine or any part thereof.

Entry.—A main haulage road, gangway, or airway. An underground passage

used for haulage or ventilation, or as a manway. Entry Stumps.—Pillars of coal left in the mouths of abandoned rooms to

support the road, entry, or gangway till the entry pillars are drawn. Erosion.—The wearing away of rocks by rains, etc.

Escaleras (Mexican).—Ladders, generally made of notched sticks.

Escarpment.-A nearly vertical natural face of rock or soil.

Escoria (Mexican).-Slag or cinders.

Escorial.—Slag pile.

Escorificador (Mexican).—A scorifier, in assaying.

Espejuelo (Mexican).—A mineral gangue, with a faintly reflecting surface.

Espejuelo (Mexican).—The tapping bar of a smelting furnace.

Estano (Spanish).—Tin.

Estrujon (Mexican).—A second collection of amalgam, generally very pasty. Exploder. - A chemical employed for the instantaneous explosion of powder. Exploitation.—The working of a mine, and similar undertakings; the examination instituted for that purpose.

Exploration.—Development.

Explosion.—Sudden ignition of a body of firedamp.

Eye (English).—(1) A circular hole in a bar for receiving a pin and for other purposes. (2) The eye of a shaft is the very beginning of a pit. (3) The eye of a fan is the central or intake opening.

Face.—(1) The place at which the material is actually being worked, either in a breast or heading or in longwall. (2) The end of a drift or tunnel. Face-On.—When the face of the breast or entry is parallel to the face cleats of the seam (see page 285).

Face Wall.—A wall built to sustain a face cut into the natural earth, in

distinction to a retaining wall, which supports earth deposited behind it.

Facnas (Mexican).—Dead work, in the way of development.
Fahlband (German).—A course impregnated with metallic sulphides.
Fulscador (Spanish).—A gold washer.
Full.—(1) A mass of roof or side which has fallen in any part of a mine.
(2) To blast or wedge down coal.

False Bedding.—Irregular lamination, wherein the laminæ, though for short distances parallel to each other, are oblique to the general strati-

fication of the mass at varying angles and directions. False Bottom.—(1) A movable bottom in some apparatus. (2) A stratum on

which pay dirt lies, but which has other layers below it.

Fulse Cleavage.—A secondary slip cleavage superinduced on slaty cleavage. Fulse Set.—A temporary set of timber used until work is far enough advanced to put in a permanent set.

mp (North of England).—Thin beds of soft tough shale. n.—A machine for creating a circulation of air in a mine.

n Drift.-A short tunnel or conduit leading from the top of the air-shaft to the fan.

nega (Mexican).-A Spanish measure of about 21 bushels.

ng (Derbyshire).—An air-course. scines (English).—Bunches of twigs and small branches for forming foundations on soft ground.

1st.—(1) A road driven in a seam with the solid coal at each side. "Fast at an end." or "fast at one side." implies that one side is solid coal and the other open to the goaf or some previous excavation. (2) Bed rock.

ust End.—An end of a breast of coal that requires cutting. ut Coals.—Those containing volatile oily matters.

FAM

athom (English).—6 ft.
ault.—A fracture or disturbance of the strata breaking the continuity of the formation.

eather.—A slightly projecting narrow rib lengthwise on a shaft, arranged to catch into a corresponding groove in anything that surrounds and slides along the shaft.

eather Edge.—(1) A passage from false to true bottom. (2) The thin end of a wedge-shaped piece of rock or coal.

eather Ore.—Sulphide of lead and antimony. eed.—Forward motion imparted to the cutters or drills of rock-drilling or coal-cutting machinery, either hand or automatic.

**Feeder. (-1) A runner of water. (2) A small blower of gas.

*Feigh (North of England).—Ore refuse.

*Fencing.—Fencing in a claim is to make a drive round the boundaries of an alluvial claim, to prevent wash dirt from being worked out by adjoining claim holders.

*Fend-Off (English).—A sort of bell-crank for turning a pump rod past the angle of a crooked shaft.

*Fend-Off (Maylen).—Iron mette

Fierros (Mexican).—Iron matte. Fiery.—Containing explosive gas.

Fines.—Very small material produced in breaking up large lumps.

Fire.—(1) A miners' term for firedamp. (2) To blast with gunpowder or other explosive. (3) A word shouted by miners to warn one another when a shot is fired.

Fire-Bars (English).—The iron bars of a grate on which the fuel rests.

Fireboard.—A piece of board with the word fire painted upon it and suspended to a prop, etc., in the workings, to caution men not to take a naked light beyond it, or to pass it without the consent of the foreman or his assistants.

Fire Boss.—An underground official who examines the mine for gas and

inspects safety lamps taken into the mine. Fireclay.—Any clay that will withstand a great heat without vitrifying.

Firedamp.—(1) A mixture of light carburetted hydrogen (CH4) and air in explosive proportions; often applied to CH_4 alone or to any explosive mixture of mine gases. Fireman.—See Fire Boss.

Fire-Setting.—The process of exposing very hard rock to intense heat, ren-

dering it thereby easier for breaking down.

First Working.—See Whole Working.

Firsts.—The best ore picked from a mine.

Fish.—To join two beams, rails, etc. together by long pieces at their sides. Fissure.—An extensive crack.

Fissure Vein.—Any mineralized crevice in the rock of very great depth.

Flags.-Broad flat stones for paving.

Flagstone.—Any kind of a stone that separates naturally into thin tabular plates suitable for pavements and curbing. Especially applicable to sandstone and schists.

Flang (Cornish).—A double-pointed pick.

Flange (English).—A projecting ledge or rim.

Flat.—(1) A district or set of workings separated by faults, old workings, or barriers of solid coal. (2) The siding or station laid with two or more lines of railway, to which the putters bring the full cars from the working face, and where they get the empty cars to take back. (3) The area of working places, from which coal is brought to the same station, is also called "flat.

Flat Rod.—A horizontal rod for conveying power to a distance.

Flats.—Narrow decomposed parts of limestones that are mineralized.

Flat Sheet.—Sheet-iron flooring at landings and in the plats, chambers, as junctions of drives, to facilitate the turning and management of truck Flat Wall (Cornish).—Foot-wall.

Flintshire Furnace.—A kind of reverberatory furnace used for smelting less

Float.—Broken and transported particles or boulders of vein matter.

Float Gold.—Gold in thin scales, which floats on water.

Float Ore.—A term applied by miners to ore found loose in the clay or soil

Float Stones.—Loose boulders from lodes lying on or near the surface. Flood Gate (English).—A gate to let off excess of water in flood or other

Floor.—(1) The stratum of rock upon which a seam of coal immediately lies. (2) That part of a mine upon which you walk or upon which the road bed is laid.

Floram (Cornish).—Very fine tin.

Flour Gold.—The finest alluvial gold.

Flouring.—Mercury reduced to fine globules that are easily contaminated and will not amalgamate.

Flucan.—A soft, greasy, clayey substance found in the joints of veins. Fluke.—A rod for cleaning out drill holes.

Flume.-An artificial watercourse.

Fluming—Lifting a river out of its bed with wooden launders or pipes in order to get at the bed for working.

Flush.—(1) To clean out a line of pipes, gutters, etc. by letting in a sudden rush of water. (2) The splitting of the edges of stone under pressure. (3) Forming an even continuous line or surface. (4) To fill a mine with fine material.

Fluthwerk (German).—River prospecting.

Flux.—Iron ore, limestone, and sand, which are added in various proportions to the charge in a furnace to make the gangue melt up and flow off easily.

Fodder (North of England).—21 cwt. of lead.
Following Stone.—Roof stone that falls on the removal of the seam.
Foot (Cornish).—2 gallons, or 60 lb., black tin.

Foot-Hole.—Holes cut in the sides of shafts or winzes to enable miners to ascend and descend.

Foot-Piece.—(1) A wedge of wood or part of a slab placed on the foot-wall against which a stull piece is jammed. (2) A piece of wood placed on the floor of a drive to support a leg or prop of timber.

Foot-Wall.—The lower boundary of a lode.

Footway.—Ladders in mines.

Force Fan.—See Blowdown Fan.

Force Piece.—Diagonal timbering to secure the ground.
Force Pump.—A pump that forces water above its valves.
Forcebay.—Penstock. The reservoir from which water passes directly to a waterwheel.

Forepoling.—Driving the poles over the timbers so that their ends project beyond the last set of timber, so as to protect the miner from roof falls: used also in quicksand or other loose material.

Forewinning.—The first working of a seam in distinction from pillar drawing.

Fork.—(1) A deep receptacle in the rock, to enable a pump to extract the bottom water. A pump is said to be "going in fork" when the water is so low that air is sucked through the windbore. (2) (Cornish) Bottom

of sump. (3) (Derbyshire) Prop for soft ground.

Formation.—A series of strata that belong to a single geological age.

Fossickers (Australian).—Grubbers for gold in the beach sand.

Fossicking.—Overhauling old workings and refuse heaps for gold

Fossil.—Organic remains or impressions of them found in mineral matter. Fother (North of England).—I chaldron.
Frame.—A table composed of boards, slightly inclined, over which water

runs to wash off waste from sluice tin.

Frame Set.—The legs and cap or collar arranged so as to support a passage mined out of the rock or lode; also called Framing.

Free.—Coal is said to be "free" when it is loose and easily mined, or when it will "run" without mining.

"ve Milling.—Ores requiring no roasting or chemical treatment.

ee Miner.-Licensed miner. esno (Mexican).—An ash tree

onton (Mexican).—Any working face. welle (Mexican).—A bellows.

irnace.—A large coal fire at or near the bottom of an upcast shaft, for producing a current of air for ventilating the mine.

urnace Shaft.—The upcast shaft in furnace ventilation.

use.—(1) A hollow tube filled with an explosive mixture for igniting cartridges. (2) To melt.

ibarro (Mexican).—Ore in large pieces, from egg size up. ad .- A small steel wedge used for loosening jointy ground. al (Cornish).—Hard gossan

alapago (Mexican).—A turtle-shaped pig of lead. ale. - A grant of mining ground.

alemador (Spanish).—A silver furnace.

aleme (Mexican).—A reverberatory furnace. See Cendradilla. 'alera (Mexican).—A shed; any long or large room; a storehouse.

'aliage.—Royalty.
'allery.—A horizontal passage.

idlos (Mexican).—Rich specimens of silver or gold ore, particularly those that show native silver or gold. *iallows Frame.*—The frame supporting a pulley over which the hoisting rope

passes to the engine.

**Rambucino (Mexican).—A prospector for gold placers or ores. **Fang.—A set of miners, a "shift."

Fangue.—Waste material from lodes.

Jangway.—The main haulage road or level.

Janister.—A hard, compact, extremely silicious fireclay.

Garabata (Mexican).—A curved iron bar used in copper smelting.
Gas.—See Firedamp. Any firedamp mixture in a mine is called gas.

Gas Coal.—Bituminous coal containing a large percentage of gas.

Gash Vcin.—A wedge-shaped vein.
Gashet.—A band or ring of any material put between the flanges of pipes before bolting, to make them water-tight or steam-tight.

Gatches (Cornish).-Final sludge from tin dressing.

Gate.—An underground road connecting a stall or breast with a main road.
Gateway.—(1) A road kept through goal in longwall working. (2) A gangway having ventilating doors.

Gauge Door.—A wooden door fixed in an airway for regulating the supply of ventilation necessary for a certain district or number of men.

Gauge Pressure.—The pressure shown by an ordinary steam gauge. It is

the pressure above that of the atmosphere.

Gears, or Pair of Gears.—(1) Two props and a plank, the plank being supported by the props at either end. (2) The teeth of a gear-wheel or

Geodes.-Large nodules of stone with a hollow in the center. Geordie. - A safety lamp invented by George Stephenson.

Geyser. - Natural fountain of hot water and steam.

Gib.-(1) A short prop of timber by which coal is supported while being holed or undercut. (2) A piece of metal often used in the same hole with a wedge-shaped key for holding pieces together. Ginneys.—See Dillies.

Gin, or Horse Gin.—A vertical drum and framework by which the minerals and dirt are raised from a shallow pit.

Giraffe.—A mechanical appliance for receiving and tipping a car full of ore or waste rock when it arrives at the surface.

Girdle.—A thin bed or band of stone. A roof is described as a post roof with metal girdles, or a metal roof with post girdles, according as the post or the metal predominates.

Glist (Cornish).—Micaceous iron ore.
Goof, or Goare.—That part of a mine from which the coal has been worked away, and the space more or less filled up with waste.

Gob.—(1) Another word for Goaf. (2) To leave coal and other minerals that are not marketable in the mine. (3) To stow or pack any useless underground roadway with rubbish

Gob Fire.—Spontaneous combustion underground of fine coal and slack in the gob.

Gobbing Up .- Filling with waste.

Gob Road.—A roadway in a mine carried through the goaf. Going Headways, or Going Bord.—A headway or bord laid with rails, an used for conveying the coal tubs to and from the face.

Golpeador (Mexican).—A striker, in hand drilling.

Gossan.—A spongy ferruginous oxide, left after the soluble substances have been dissolved out of a lode.

Goths (Staffordshire).-Sudden burstings of coal from the face, owing to

tension caused by unequal pressure. Gouge.—The layer of clay, or decomposed rock, that lies along the wall of

walls of a vein. It is not always valueless.

Grade.—The amount of fall or inclination in ditches, flumes, roads, etc. Grain.—An obscure vertical cleavage usually more or less parallel to the end

or dip joints.

Granza (Mexican).—Metallic minerals from the size of rice to that of hens' eggs.

Grasa (Mexican).-Literally, grease. Slags.

Grass.-The surface of the ground.

Grassero (Spanish).—Slag heap.

Grate Coal.—See Broken Coal.

Grating.—A perforated iron sheet or wire gauze placed in front of reducing machinery.

Gravel,-Water-worn stones about the size of marbles.

Gray Metal.-Shale of a grayish color.

Graywacke.-A compact gray sandstone frequently found in Paleozoic formations.

Greenstone.—A general term employed to designate green-colored igneous rocks, as diorite, dolerite, diabase, gabbro, etc.

Grena (Spanish).—Undressed ore.
Greta (Mexican).—Impure litharge formed in a reverberatory furnace.

Griddle.—A coarse sieve used for sifting ores, clay, etc.

Grizzly.-A grating to throw out large stones from hydraulic gold sluices. Ground Rent.-Rent paid for surface occupied by the plant, etc. of a

colliery. Groundsill.—A log laid on the floor of a drive on which the legs of a set of timber rest.

Ground Sluicing.—Washing alluvial, loosened by pick and shovel, in trenches cut out of the bed rock, using bars of rock as natural riffles. Used in shallow placers, hill claims, bank claims, and stream diggings.

Grout (English).—Thin mortar poured into the interstices between stones

and bricks

Grove (Derbyshire).—A mine.

Grub Stake.—The mining outfit or supplies furnished to a prospector on condition of sharing in his finds.

Grueso (Mexican).-Lump ore.

Grundy.—Granulated pig iron.
Guag (Cornish).—Worked-out ground.

Gualdria (Mexican).—A long and stout beam, generally sustaining other beams or some heavy weight.

Guano.—A brown, gray, or white, light powdery deposit, consisting mainly of the excrement of sea fowl in rainless tracts, or of bats in caves.

Guarda Raya (Mexican).—A landmark; a monument.
Guardas (Mexican).—The country seat immediately enclosing any metalliferous vein or deposit.

Gubbin.-Ironstone.

Guia (Mexican).—Indications where to cut a pay streak or to find a vein. Guides.—See Cage Guides.

Guija (Spanish).—Quartz.

Guijo (Mexican).-A pointed pivot, upon which turns the upright center piece of an arrastre, of a door, etc.

Gunboat.—A self-dumping car, holding from 5 to 8 tons of coal, used upon They are filled by emptying the mine cars inclined planes or slopes. into them at the foot of the slope.

Gunnies (Cornish).-3 ft.

Gurt (Cornish).—Water runnel from dressing floor.
Gutter.—(1) A small water-draining channel. (2) The lowest part of a lead that contains the most highly auriferous dirt.

lacienda de Beneficio (Mexican).-In mining, a metallurgical works; any metallurgical works, usually an amalgamation works.

Hacienda de Fundicion (Mexican).—A smelting works. Hacienda de Maquila (Mexican).—A custom mill.

Hade.—The inclination of a vein or fault, taking the vertical as zero.

Hatarn (Wales).—Iron.
 Half Course.—(1) At an angle of 45° from general or previous course. (2)
 Half on the level and half on the dip.

Half Set.—One leg piece and a cap

Halvans.—Gangue containing a little ore.

Hammer-and-Plate.—A signaling apparatus.

Hand Barrow.—A long box with handles at each end.

Hand Dog.—A kind of spanner or wrench for screwing up and disconnecting the joints of boring rods at the surface.

Handspike.—A wooden lever for working a capstan or windlass.

Handwhip.—An apparatus used in shallow alluvial workings, consisting of

an upright, at the top of which is balanced a long sapling; at the thick end of the sapling, a bag of earth is fastened to counterbalance the bucket of dirt to be raised at the other end.

Hanger-On.—The man that runs the loaded cars on to the cages and gives the signal to hoist. See Cager.

Hanging Spear Rod. - Wooden pump rods adjustable by screws, etc. by which a sinking set of pumps is suspended in a shaft.

Hanging Wall.—In metalliferous mining, the stratum lying geologically directly above a bed or vein.

Hardhead.-Residue from tin refining; contains much iron and arsenic.

Harrow.-Somewhat like an agricultural harrow; it is fixed to the pole of a puddling machine and dragged around to break up and mix the auriferous clays with water.

Hatajo (Mexican).—A drove of pack mules.

Hat Rollers.—Cast-iron or steel rollers shaped like a hat, revolving on a vertical pin, for guiding inclined haulage ropes around curves.

Hatter.—A miner working by himself on his own account.

Haulage Clip.-Levers, jaws, wedges, etc. by which cars, singly or in trains, are connected to the hauling ropes.

Hauling.—The drawing or conveying of the product of the mine from the working places to the bottom of the hoisting shaft, or slope.

Haunches.—The parts of an arch from the keystone to the skew back.

Hazle (North of England).—Sandstone mixed with shale.

Head.—(1) Pressure of water in pounds per square inch. (2) Any subterranean passage driven in solid coal. (3) That part of a face nearest

Head, or Sluice Head (Australia and New Zealand).—A supply of 1 cu. ft. of

water per second, regardless of the head, pressure, or size of orifice.

Head-Block.—(1) A stop at the head of a slope or shaft to stop cars from

going down the shaft or slope. (2) A cap piece.

Headboard.—A wedge of wood placed against the hanging wall, and against

which one end of the stull piece is jammed.

Header.—(1) A rock that heads off or delays progress. (2) A blast hole at or above the head. (3) A stone or brick laid lengthwise at right angles to the face of the masonry. (4) The Stanley Header is an entry boring machine that bores the entire section of the entry in one operation.

Head-Gear.—The pulley frame erected over a shaft. Head-House.—When the head-frame is housed in, the structure is known by

this name. Heading.-(1) A continuous passage for air or for use as a manway; a gangway or entry. (2) A connecting passage between two rooms, breasts, or other working places.

Head-Piece.—A cap; a collar.

Headrace.—An aqueduct for bringing a supply of water on to the ground.

Headstocks.—Gallows frame; head-frame.

Headways.—(1) A road; usually 9 ft. wide, in a direction parallel to the main-cleavage planes of the coal seams, which direction is called "headways course," and is generally about north and south in the Newcastle coal field. It is termed "on end" in other districts. (2) Cross-headings.

Heave.—The shifting of rocks, seams, or lodge on the face of a cross-course, etc.

Heaving.—The rising of the thill (or floor) of a seam where the coal has been removed.

Hechado (Spanish),-Dip.

Heel of Coal.—A small body of coal left under a larger body as a support. Heel of a Shot .- In blasting, the front of a shot, or the face of the shot farthest

from the charge.

Heep Stead (English).—The entire surface plant of a colliery.

Helper.—A miner's assistant, who works under the direction of the miner. *Helve.*—A handle.

Hewer.—A collier that cuts coal; a digger.

High Reef.—The bed rock or reef is frequently found to rise more abruptly on one side of a gutter than on the other, and this abrupt reef is termed a high reef.

Hijuelas (Mexican).—Literally, little children. A small-sized torta made up as a sort of assay on a large scale, with from 1 to 5 kilograms of argentiferous mud.

Hill Diggings.—Placers on hills.

Hilo (Spanish).—A thin metalliferous vein.

Hitch.—(1) A fault or dislocation of less throw than the thickness of the seam in which it occurs. (2) Step cut in the rock or lode for holding stay-beams, beams, or timber, etc. for various purposes.

Hoarding.—A temporary close fence of boards placed around a work in

progress.

Hogback.—A roll occurring in the floor and not in the roof, the coal being

cut out or nearly so, for a distance. Hoister.—A machine used in hoisting the product. It may be operated by

steampower or horsepower.

Hole.—(1) To undercut a seam of coal by hand or machine. (2) A bore holè. (3) To make a communication from one part of a mine to

another.

Holing.—(1) The portion of the seam or underclay removed from beneath the coal before it is broken down. (2) A short passage connecting two

roads. (3) See Kirving.

Holing Through.—Driving a passage through to make connection with another part of the same workings, or with those in an adjacent mine.

Hopper.—A coal pocket; a funnel-shaped feeding trough.

Horn .- A piece of bullock's horn about 8 in. in length, cut boat-shaped, for concentrating by water on a small scale.

Horn Coal.—Coal worked partly end-on and partly face-on.

Horn Silver.—Chloride of silver.

Horse Gin.—A gearing for winding by horsepower.

Horsepower.—The power that will raise 33,000 lb. 1 ft. high per minute.

Horse, or Horsebacks.-(1) Natural channels cut or washed away by water in a coal seam, and filled up with shale and sandstone. Sometimes a bank or ridge of foreign matter in a coal seam. (2) A mass of country rock lying within a vein or bed. (3) Any irregularity cutting out a portion of the vein. See Dirt Fault and Rock Fault.

Horse Whim.—A vertical drum worked by a horse, for hauling or hoisting.

Called also Horse Gin.

Hose.—A strong flexible pipe made of leather, canvas, rubber, etc., and used for the conveyance of water, steam, or air under pressure to any particular point.

H Piece.—The portion of a column pipe containing the valves of the pump.

Hucco (Mexican).—See Demasia. Hulk (Cornish).—To pick out the soft portions of a lode.

Hundido (Mexican).—See Derrumbe.

Hungry.—Worthless looking.
Hurdy Gurdy.—A waterwheel that receives motion from the force of traveling water.

Hushing.-Prospecting by laying ground bare by sudden discharges of pent-up water.

Hutch (Cornish).—(1) An ore-washing box. (2) (English) A mine car. Hydraulic Cement.—A mixture of lime, magnesia, alumina, and silica that solidifies beneath water.

Hydraulicking.-Working auriferous gravel beds by hydraulic power.

Hydrocarbons.—Compounds of hydrogen and carbon.

gneous Rocks.—Those that have been in a more or less fused state.

Inbye.—In a direction inward toward the face of the workings, or away from the entrance.

Incline.—Short for inclined plane. Any inclined heading or slope road or

track having a general inclination or grade in one direction.

Incorporo (Mexican).—The act of adding and mixing the mercury and other ingredients in and to the metalliferous mud for the patio process of amalgamation. Incorporadero.—Place where the incorporo effected.

Indicator.—(1) A mechanical contrivance attached to winding, hauling, or other machinery, which shows the position of the cages in the shaft or the cars on an incline during its journey or run. (2) An apparatus for showing the presence of firedamp in mines, the temperature of goaves, the speed of a ventilator, pressure of steam, air, or water, etc.

Indicator Card, or Diagram.—A diagram showing the variation of steam pressure in the cylinder of an engine during an entire stroke or revo-lution.

Indoor Catches.—Strong beams in Cornish pumping-engine houses to catch the beam in case of a smash, thus preventing damage to the engine

In-fork.—When a pump continues working after water has receded below the holes of the wind bore.

Ingot.—A lump of cast metal.

In Place.—A vein or deposit in its original position.

Insalmoro (Mexican).—The addition of salt to the torts or mud heap.

Inset.—The entrance to a mine at the bottom, or part way down a shaft where the cages are loaded.

Inside Slope.—A slope on which coal is raised from a lower to a higher gangway.

Inspector. - A government official whose duties are to enforce the laws regu-

lating the working of mines. Instroke.—The right to take coal from a royalty to the surface by a shaft in

an adjoining royalty. A rent is usually charged for this privilege.

Intake.—(1) The passage through which the fresh air is drawn or forced in a mine, commencing at the bottom of a downcast shaft, or the mouth of a slope. (2) The fresh air passing into a colliery.

Inversion.—Such a change in the dip of a vein or seam as makes the footwall or floor the upper and the hanging wall or roof the lower of

the two.

Irestone (Cornish).-Any hard tough stone.

Iron Hat.—Decomposed ferruginous mineral capping a lode.

Iron Man.—A coal-cutting machine.

Jaboncillo (Mexican).—Decomposed talcose rock or hardened clay, generally found in a vein, and sometimes indicating the proximity of a rich strike. Jacal (Mexican).—See Xacal.

Jack.—A lantern-shaped case made of tin, in which safety lamps are carried in strong currents of air.

Jacket.—(1) An extra surface covering, as a steam jacket. (2) A water-

jacket is a furnace having double iron walls, between which water circulates.

Jack-Lamp.—A Davy lamp, with the addition of a glass cylinder outside the gauze.

Jacotinga (Brazilian).—Ferruginous ores associated with gold.

Jales (Spanish).—Tailings.

Jales-Jalsontles (Mexican).—Rich tailings or middlings from concentration or amalgamation.

Jars.—In rope drilling, two long links which take up the shock of impact when the falling tools strike the bottom of the hole.

Jenkin.—A road cut in a pillar of coal in a bordways direction, that is, at right angles to the main-cleavage planes.

Jig.—(1) A self-acting incline. (2) A machine for separating ores or minerals from worthless rock by means of their difference in specific gravity;

also called Jigger or Washer.

Jigger.—(1) A kind of coupling hook for connecting cars on an incline.

(2) An allowance of liquor sometimes issued to workmen (almost obsolete). (3) See Jig.

Jigging.—Separating heavy from light particles by agitation in water.

Jockey .- A self-acting apparatus carried on the front truck of a set for releasing it from the hauling rope.

Joggle. - A joint of trusses or sets of timber for receiving pressure at right

angles, or nearly so.

Joints.—(1) Divisional planes that divide the rock in a quarry into natural Joints.—(1) Divisional planes that divide the rock in a quarry into natural blocks. There are usually two or three nearly parallel series, called by quarrymen end joints, back joints, and bottom joints, according to their position. (2) In coal seams, the less pronounced cleats or vertical cleavages in the coal. The shorter cleats about at right angles to the face cleats and the bedding plane of the coal.
Jud.—(1) A portion of the working face loosened by "kirving" underneath and "nicking" up one side. The operation of kirving and nicking is spoken of as "making a jud." (2) The term jud is also applied to a working place, usually 6 to 8 yd. wide, driven in a pillar of coal. When a jud has been driven the distance required, the timber and rails are removed, and this is termed "drawing a jud."
Judge (Derbyshire and North of England).—A measuring staff.
Jugglers, or Jugulars.—Timbers set obliquely against the rib in a breast to form a triangular passage to be used as a manway, airway, or chute.

form a triangular passage to be used as a manway, airway, or chute.

Jump.—An upthrow or a downthrow fault.

Jumper.—A hand drill used in boring holes in rock for blasting.

Kann (Cornish).—Fluorspar.

Kazen (Cornish).—A sieve.

Joc

Keckle-Meckle .- Poorest lead ore.

Keeker.—An official that superintends the screening and cleaning of the coal. Keel Wedge.—A long iron wedge for driving over the top of a pick hilt.

Keeps, or Keps.—Wings, catches, or rests to hold the cage at rest when it reaches any landing.

Keeve.—A large wooden tub used for the final concentration of tin oxide. Kenner.—Time for quitting work.

Kerf.—The undercut made to assist the breaking of the coal.

Kerned (Cornish).-Pyrites hardened by exposure.

Kerve (North of England).—In coal mining, to cut under. Kevil (Derbyshire).—Calcspar found in lead veins.

Key.-(1) An iron bar of suitable size and taper for filling the keyways of shaft and pulley so as to keep both together. (2) A kind of spanner

used in deep boring by hand.

Kibble.—See Bowk. Often made with a bow or handle, and carrying over a

ton of débris. Kickup.—An apparatus for emptying trucks. Kieve.—Tossing tub.

Killas (Cornish).—Clay slate.

Kiln.—A chamber built of stone or brick, or sunk in the ground, for burning minerals in.

Kind.—(1) Tender, soft, easy. (2) Likely looking stone. Kind-Chaudron.—A system of sinking shafts through water-bearing strata.

Kirving (North of England).—The cutting made beneath the coal seam.

Kist.—The wooden box or chest in which the deputy keeps his tools. chest is always placed at the flat or lamp station, and this spot is often

referred to by the expression "at the kist. Kit.—Any workman's necessary outfit, as tools, etc.

Kitty.—A squib made of a straw tube filled with powder.

Knee Piece.—A bent piece of piping.

Knocker.—A lever that strikes on a plate of iron at the mouth of a shaft, by

means of which miners below can signal to those on the top.

Knocker Line.—The signal line extending down the shaft from the knocker. Koepe System.—A system of hoisting without using drums, the rope being endless and passing over pulleys instead of around a drum.

Labor (Mexican).-Mine workings in general. Specifically, a stope or any other place where ore is being taken out.

Ladderway, Ladder Road.—The particular shaft, or compartment of a shaft, used for ladders.

Lagging.-(1) Small round timbers, slabs, or plank, driven in behind the legs and over the collar, to prevent pieces of the sides or roof from falling through. (2) Long pieces of timber closely fitted together and fastened to the drum rings to form a surface for the rope to wind on.

Lamas (Spanish).—(1) Slimes. (2) Argentiferous mud treated by amalgamation.

Lamero (Mexican).—Place of deposit for lamas.

Lamina.—Sheets not naturally separated, but which may be forced apart. Lampazo (Mexican).—A sort of broom formed of green branches on the end

of a long stick, to dampen the flame in a reverberatory furnace. Lamp Men.—Cleaners, repairers, and those having charge of the safety lamps

at a colliery.

Lamp Stations.—Certain fixed stations in a mine at which safety lamps are allowed to be opened and relighted by men appointed for that purpose, or beyond which, on no pretense, is a naked light allowed to be taken.

Lander.—The man that receives a load of ore at the mouth of a shaft.

Lander's Crook.—A hook or tongs for upsetting the bucket of hoisted rock. Landing.—(1) A level stage for loading or unloading a cage or skip.
 (2) The top or bottom of a slope, shaft, or inclined plane.

Land Sale.—The sale of coal loaded into carts or wagons for local consumption.

Land-Sale Collieries.—Those selling the entire product for local consumption, and shipping none by rail or water.

Lap.—One coil of rope on a drum or pulley.

Lappior (Cornish).—An ore dresser.

Large.—The largest lumps of coal sent to the surface, or all coal that is hand picked or does not pass over screens; also, the large coal that passes over screens.

Larry.—(1) A car to which an endless rope is attached, fixed at the inside end of the road, forming part of the appliance for taking up slack rope. See Balance Car. (2) See Barney. (3) A car with a hopper bottom and adjustable clutes for feeding coke ovens. (4) A hopper-shaped car for charging coke ovens.

Latches.—(1) A synonym of switch. Applied to the split rail and hinged

switches. (2) Hinged switch points, or short pieces of rail that form

rail crossings.

Lateral.-From the side. Lath.—A plank laid over a framed center or used in poling.

Launder.—Water trough.

Laundry Box.—The box at the surface receiving the water pumped up from

Lava.—A common term for all rock matter that has flowed from a volcano or fissure.

Lavadero (Mexican).—A washer. A tank with a stirring arrangement to loosen up the argentiferous mud from the patio, and dilute the same with water, so that the silver amalgam may have a chance to precipitate. An agitator.

Lazadores (Mexican).—Men formerly employed in recruiting Indians for work in the mines by the gentle persuasion of a lasso.

Lazy Back (Staffordshire).—A coal stack, or pile of coal.

Leaching.—To dissolve out by some liquid.

Lead (pronounced leed).—(1) Ledge (America); reef (Australia); lode or vein (England). A more or less vertical deposit of ore formed after the rock in which it occurs. (2) A bed of alluvial pay dirt or an auriferous (3) The distance to which earth is hauled or wheeled.

Leader.—A seam of coal too small to be worked profitably, but often being a

guide to larger seams lying in known proximity to it. Leat.-A small water ditch.

Leavings (Cornish).—Halvans.

Ledge.-See Lead.

Leg.—A wooden prop supporting one end of a collar.

Leg Piece.—An upright log placed against the side of a drive to support the cap piece.

Lenador (Mexican).—One that cuts, carries, or furnishes wood for combustible.

Level.—A road or gangway running parallel or nearly so with the strike of the seam.

Ley (Mexican).—Law. As applied in mining matters, it means the proportion of precious or other metals contained in any mineral substance or metallic alloy.

Lid.—A cap piece used in timbering.

Lift.—(1) The vertical height traveled by a cage in a shaft. (2) The lift of pump is theoretical height from the level of the water in the sump to the point of discharge. (3) The distance between the first level and the sump to surface, or between two levels. (4) The levels of a shaft or slope.

Lifting Guards.—Fencing placed around the mouth of a shaft, which lifted out of the way by the ascending cage.

Lignite.—A coal of a woody character containing about 66% carbon and having a brown streak.

Limadura (Mexican).—Filings. The mercurial globules seen when a pied of argentiferous mud from a patio is washed in a spoon or saucer for

an assay.

Lime Cartridge.—A charge or measured quantity of compressed dry caustic lime made up into a cartridge and used instead of gunpowder for breaking down coal. Water is applied to the cartridge, and the expansion breaks down the coal without producing a flame.

Lime Coal.—Small coal suitable for lime burning.

Lines.—Plumb-lines, not less than two in number, hung from hooks driven in wooden plugs. A line drawn through the centers of the two strings or wires, as the case may be, represents the bearing or course to be

Lining.—The planks arranged against frame-sets.
Linnets (Derbyshire).—Oxidized lead ores.
Linternilla (Mexican).—The drum of a Horse Whim.

Lip Screen.—A small screen or screen bars, placed at the draw hole of a coal pocket to take out the fine coal.

Lis (Mexican).—The flouring of mercury.

Little Giant.—The name given to a special sort of hydraulic nozzle used for sluicing purposes.

Live Quartz.—A variety of quartz usually associated with mineral. Lixiviating.—See Leaching.

Llaves (Mexican).—Horizontal cross-beams in a shaft, or the upright pieces

that sustain the roof beams in a drift or tunnel. Loaded Track.-Track used for loaded cars.

Loader.—One that fills the mine cars at the working places.

Loam.—Any natural mixture of sand and clay that is neither distinctly sandy

nor clayey.

Location.—The first approximate staking out or survey of a mining claim, in distinction from a Patent Survey, or a Patented Claim.

Location Survey.—See Location.

Lode (Cornish).—Strictly a fissure in the country rock filled with mineral; usually applied to metalliferous lodes. In general miners' usage, a lode. vein, or ledge is a tabular deposit of valuable minerals between definite boundaries. Whether it be a fissure formation or not is not always known, and does not affect the legal title under the United States federal and local statutes and customs relative to lodes. But it must not be a placer, i. e., it must consist of quartz or other rock in place; and bearing valuable mineral.

Lodestone, or Lode.—(1) Magnetic iron ore. (2) Stone found in veins or lodes. Logs.—Portions of trunks of trees cut to lengths and built up so as to raise the mouth or collar of a shaft from the surface, in order to give the

requisite space for the dumping of mullock and ore.

Long-Pillar Work.—A system of working coal seams in three separate opertions: (1) large pillars are left; (2) a number of parallel headings are driven through the block; and (3) the ribs or narrow pillars are worked away in both directions.

Long Tom.—A wooden sluice about 24 ft. long, 2 ft. wide, and 1 ft. high, for washing auriferous gravel.

Long Ton .- 2,240 lb.

Longwall.—A system of working a seam of coal in which the whole seam is taken out and no pillars left, excepting the shaft pillars, and sometimes

the main-road pillars.

Loob (Cornish).—Sludge from tin dressing.

Loose End.—(1) A portion of a seam worked on two sides. (2) A portion that projects in the shape of a wedge between previous workings.

Low Grade. Not rich in mineral.

Lumber.—Timber cut to the various sizes and shapes for carpenters' purposes.

Lumbreras (Mexican).—Ventilating shafts in a mine or other underground work.

Lump Coal.—(1) All coal (anthracite only) larger than broken coal, or, when steamboat coal is made, lumps larger than this size. (2) In soft coal, all coal passing over the nut-coal screen.

Lute.—An adhesive clay used either to protect any iron vessel from too strong a heat or for securing air- and gas-tight joints.

Lue (English).—A siding or turnout.

Machote (Mexican).-A stake or permanent bench mark fixed in an underground working, from which the length and progress thereof is measured.

Macizo (Spanish).-Unworked lode.

Magistral (Spanish).—Roasted copper pyrites, copper sulphate, etc., used to reduce silver ores.

Magnetic Needle.—Needle used in surveying.

Magnetic North.—The direction indicated by the north end of the magnetic needle

Magnetic Meridian.—The line or great circle in which the magnetic needle sets at any given place.

Main Road.—The principal haulage road of a mine from which the several

crossroads lead to the working face. Main Rod (English).—See Pump Rod.

Main Rope.—In tail-rope haulage, the rope that draws the loaded cars

Makings (North of England).—Small coal produced in kirving. Fines.

Malacate (Mexican).—A Horse Whim; now extended to any hoisting machine used in mines.

Mamposteria (Mexican).—Mason work.

Manager.—An official who has the control and supervision of a mine, both under and above ground.

Man Engine.—An apparatus consisting of one or two reciprocating rods, to which suitable stages are attached, used for lowering and raising men in shafts.

Manga (Spanish).—Canvas bag for straining amalgam.

Manhole.—(1) A refuge hole constructed in the side of a gangway, tunnel, or slope. (2) A hole in cylindrical boilers through which a man can get into the boiler to examine and repair it.

Mano (Mexican).—A grinding stone of an arrastre, etc.

Mantas (Mexican).—Jute or henequen, etc., sacks in which ore or waste is carried. Manteo (Mexican).—The act of hoisting ore or waste from a mine.

Manto (Mexican).-A blanket vein.

Manway.—A small passage used as a traveling way for the miner, and also

often used as an airway or chute, or both. Maquilla (Spanish).—A custom mill. Maguilar (Mexican).—To work ore for its owner on shares or for a money

payment. Marco (Mexican).—A weight of 8 oz.

Marl.—Clay containing calcareous matter.

Marlinespike.—A sharp pointed and gradually tapered round iron, used in splicing ropes.

Marmajas (Spanish).—Concentrated sulphides.

Marrow.—A partner. Marsaut Lamp—A type of safety lamp whose chief characteristic is the multiple-gauze chimneys.

Marsh Gas.—CH., often used synonymously with Firedamp (see page 348).

Match.—(1) A charge of gunpowder put into a paper several inches long, and used for igniting explosives. (2) The touch end of a squib.

Matte.—A compound of iron and other metals, chiefly copper, with sulphur,

formed during smelting.

Mattock.—A kind of pick with broad ends for digging.

Maul.—A driver's hammer.

Maundril.—A pick with two shanks and points, used for getting coal, etc. Mazo (Mexican).—A stamp.

Mear (Derbyshire).—32 yd. along the vein.

Measures.—Strata.

Mecha (Mexican).—A wick for a lamp or candle; a torch.

Merced (Mexican).—A gift, grant, or concession.

Meridian.—A north and south line, either true or approximate.

Metal.—(1) In coal mining, indurated clay or slate. (2) An element that forms a base by combining with oxygen that is solid at ordinary temperature (with exception of quicksliver), opaque (except in the thinnest possible films), has a metallic luster, and is a good conductor of heat and electricity, and, as a rule, of a higher specific gravity than the nonmetals. (3) (Mexican) All kinds of metalliferous minerals are called "metal" in Mexico. Metal de Ayuda.—Fluxing ore of any kind. Metal de Cebo.—Very rich ore, usually treated in small reverberatory furnaces. Metal Ordinaria—(componers. Metal Person.—The best class of selected. Metal Ordinario.—Common ore. Metal Pepena.—The best class of selected

Metlapil (Mexican).—See Mano.

MET

Mill.—Works for crushing and amalgamating gold and silver ores.

Mill Cinder.—The slag from the puddling furnace of a rolling mill.

Mill Hole.—An auxiliary shaft connecting a stope or other excavation with the level below. Mill Run.—The test of a given quantity of ore by actual treatment in a mill.

Mine.—Any excavation made for the extraction of minerals.

Miner.—One who mines.

Mineral.—Any constituent of the earth's crust that has a definite composition.

Mineral Oil.—Petroleum obtained from the earth, and its distillates.

Minero (Mexican).—A mine owner; a mining captain; an underground boss. Mine Road.—Any mine track used for general haulage.

Mine Run.—The entire unscreened output of a mine.

Minero Mayor (Mexican).—The head mining captain. A mining workman is called Operario.

Miners' Dial.—An instrument used in surveying underground workings.

Miners' Inch.—A measure of water varying in different districts, being the

quantity of water that passes through a slit 1 in. high, of a certain width under a given head (see page 136).

Miner's Right.—An annual permit from the Government to occupy and work

mineral land. Mining.—In its broad sense, it embraces all that is concerned with the extraction of minerals and their complete utilization.

Mining Engineer .- A man having knowledge and experience in the many

departments of mining. Mining Retreating.—A process of mining by which the vein is untouched until after all the gangways, etc. are driven, when the mineral extraction

begins at the boundary and progresses toward the shaft. Mistress (North of England).—A miner's lamp.

Mock Lead (Cornish).—Zinc blende. Mogrollo (Mexican).—Same as Metal de Cebo.

Moil.—A short length of steel rod tapered to a point, used for cutting

hitches, etc. Molonque (Mexican).—A rich specimen of which one-half or more is native silver.

Monitor.—See Gunboat.

Monkey .- The hammer or ram of a pile driver.

Monkey Drift.-A small drift driven in for prospecting purposes, or a crosscut driven to an airway above the gangway.

Monkey Gangway -A small gangway parallel with the main gangway.

Monkey Rolls.—The smaller rolls in an anthracite breaker.

Monkey Shaft.—A shaft rising from a lower to a higher level.

Monoclinal.—Applied to an area in which the rocks all dip in the same

direction. Mop .- Some material surrounding a drill in the form of a disk, to prevent

water from splashing up.

Mortar.—The vessel in which ore is placed to be pulverized by a pestle.

Mortise.—A hole cut in one piece of timber, etc. to receive the tenon that projects from another piece.

Mote (Moat).—A straw filled with gunpowder, for igniting a shot.

Mother Gate.—The main road of a district in longwall working.

Mother Lode (Main Lode).—The principal vein of any district.

Motive Column.—The length of a column of air whose weight is equal to the difference in weight of like columns of air in downcast and upcast shafts. The ventilating pressure in furnace ventilation is measured by the difference of the weights of the air columns in the two shafts.

" ath.—The top of a shaft or slope, or the entrance to a drift or tunnel.

Moy

Moyle.—An iron with a sharp steel point, for driving into clefts when levering off rock.

Muckle.—Soft clay overlying or underlying coal.
Mucks (Staffordshire).—Bad earthy coal.
Mucsos (Mexican).—Notches in a stick; mortises; notches cut in a round
or square beam, for the purpose of using it as a ladder.
Mucseler Lamp.—A type of safety lamp invented and used in the collieries
of Belgium. Its chief characteristic is the inner sheet-iron chimney for increasing the draft of the lamp.

Muffle.—A thin clay oven heated from the outside.

Muller.—The upper grinding iron or rubbing shoe of amalgamating pans, etc.

Mullock.—Country rock and worthless minerals taken from a mine.

Mundic.-Iron pyrites.

Naked Light.—A candle or any form of lamp that is not a safety lamp. Narrow Work.—(1) All work for which a price per yard of length driven is paid, and which, therefore, must be measured. (2) Headings, chutes, crosscuts, gangways, etc.
Natas (Mexican).—Same as Escoria or Grasa.

Native Metal.—A metal found naturally in that state.

Natural Ventilation.—Ventilation of a mine without either furnace or other artificial means; the heat imparted to the air by the strata, men, animals and lights in the mine causing it to flow in one direction, or to ascend.

Neck.—A cylindrical body of rock differing from the country around it.

Needle.—(1) A sharp-pointed metal rod with which a small hole is made through the stemming to the cartridge in blasting operations. (2) A hitch cut in the side rock to receive the end of a timber.

Negrillo (Mexican).—Black sulphide of silver.

Nick.—To cut or shear coal after holing.

Nicking.—(1) A vertical cutting or shearing up one side of a face of coal. (2) The chipping of the coal along the rib of an entry or room which is usually the first indications of a squeeze.

Night Shift.—The set of men that work during the night.

Nip.—When the roof and floor of a coal seam come close together, pinching the coal between them. Nip Out.—The disappearance of a coal seam by the thickening of the adjoin-

ing strata, which takes its place.

Nitro.—A corrupted abbreviation for nitroglycerine or dynamite. Nittings.-Refuse of good ore.

Nodular.—Blistered or kidney-shaped ore.

Nodules.—Concretions that are frequently found to enclose organic remains. Nogs.-Logs of wood piled one on another to support the roof. See Chock.

Nook.—The corner of a working place made by the face with one side.

Noria (Spanish).—An endless chain of buckets.

Nozzie.—The front nose piece of bellows of a blast pipe for a furnace, or of a water pipe. Nugget.—A natural lump of gold or other metal, applied to any size above 2

to 3 dwt.

Nut Coal.—A contraction of the term chestnut coal.
Nuts.—Small lumps of coal that will pass through a screen or bars, the spaces between which vary in width from 4 to 24 in.

Costs (Mexican).—Pitch pine.

Odd Work.—Work other than that done by contract, such as repairing roads, constructing stoppings, dams, etc.

Offlake.—The raised portion of an upcast shaft above the surface, for carrying off smoke and steam, etc., produced by the furnaces and engines under-

ground.

Oil Shale.—Shale containing such a proportion of hydrocarbons as to be capable of yielding mineral oil on slow distillation.

Oil Smellers.—Men that profess to be able to indicate where petroleum oil is to be found.

Old Man.—Old workings in a mine.

Oolitic .- A structure peculiar to certain rocks, resembling the roe of a fish.

Open Cast .- Workings having no roof.

Open Cutting.—(1) An excavation made on the surface for the purpose of getting a face wherein a tunnel can be driven. (2) Any surface excavation. Openings, An Opening.—Any excavation on a coal or ore bed, or to reach the same; a mine.

Openwork.—An open cut.

Operario (Mexican).-A working miner.

Operator. - The individual or company actually working a colliery.

Ore.—A mineral of sufficient value (as to quality and quantity), to be mined with profit.

Ores.—Minerals or mineral masses from which metals or metallic combinations can be extracted on a large scale in an economic manner.

Ore Shoot.—A large and usually rich aggregation of mineral in a vein. Distinguished from pay streak in that it is a more or less vertical zone or chimney of rich vein matter extending from wall to wall, and having a definite width laterally.

Oro (Spanish).—Gold.

Oroche (Spanish).—(1) Retorted bullion. (2) (Mexican) Bullion containing gold and silver.

Outburst.—A blower. A sudden emission of large quantities of occluded gas. Outbye.—In the direction of the shaft or slope bottom, or toward the outside. Outcrop.—The portion of a vein or bed, or any stratum appearing at the surface, or occurring immediately below the soil or diluvial drift.

Outcropping.—See Cropping Out.

Outlet .- A passage furnishing an outlet for air, for the miners, for water. or for the mineral mined.

Output.—The product of a mine sent to market, or the total product of a mine. Outset. - The walling of shafts built up above the original level of the ground. Outstroke Rent.—The rent that the owner of a royalty receives on coal brought into his royalty from adjacent properties.

Outtake.—The passage by which the ventilating current is taken out of the

mine; the upcast.

Overburden.-The covering of rock, earth, etc. overlying a mineral deposit that must be removed before effective work can be performed.

Overcast.—A passage through which the ventilating current is conveyed over a gangway or airway.

Overhand Stoping.—The ordinary method of stoping upwards.

Overlap Fault.—A fault in which the shifted strata double back over themselves.

Overman.—One who has charge of the workings while the men are in the mine. He takes his orders from the Underviewer.

Overwind.—To hoist the cage into or over the top of the head-frame. Oyamel (Mexican).—White pine.

Pack.—A rough wall or block of coal or stone built up to support the roof. Packing.—The material placed in stuffingboxes, etc. to prevent leaks. Pack Wall.—A wall of stone or rubbish built on either side of a mine road, to carry the roof and keep the sides up.

Pacos (Spanish).—Ferruginous silver ores.

Paddock.—(1) An excavation made for procuring wash dirt in shallow ground. (2) A place built near the mouth of a shaft where ore is stored. Paint Gold.—The very finest films of gold coating other minerals. Paleozoic.—The oldest series of rocks in which fossils of animals occur.

Palero (Mexican).—A mine carpenter.

Palm.—A piece of stout leather fitting the palm of the hand, and secured by a loop to the thumb; this has a flat indented plate for forcing the needle. Palm Needle. - A straight triangular-sectioned needle, used for sewing canvas. Palo (Mexican).—A stick; a piece of timber.

Pan.—A thin sheet-iron dish 16 in. across the top, and 10 in. at the bottom,

used for panning gold.

Panel.—(1) A large rectangular block or pillar of coal measuring, say, 130 by 100 yd. (2) A group of breasts or rooms separated from the other workings by large pillars.

Panel Working.—A system of working coal seams in which the colliery is divided up into large squares or panels, isolated or surrounded by solid ribs of coal, in each of which a separate set of breasts and pillars is worked, and the ventilation is kept distinct, that is, every panel has its own circulation, the air of one not passing into the adjoining one, but being carried direct to the main return airway.

Porvino (Mexican).—The peculiar appearance, form, or manner in which the metalliferous minerals present themselves in any given district

Panning, or Punning Off.—Separating gold or tin from its accompanying minerals by washing off the latter in a pan.

Parcionero (Mexican).—A partner in a mining contract.

Parrot Coal.—A kind of coal that splits or cracks with a chattering noise when on the fire

Partido (Mexican).—The division of ores between partners. Working a mine by partido is when the miners agree with the owners to take a certain part of the ores in place of wages. Usually, the mine owner provides candles, powder, and steel, and keeps the drills sharpened, and receives, in payment of royalty and supplies, two-thirds or more of the ore taken out. This contract is renewed weekly or monthly, etc., and the proportion of ore retained by the miners is more or less, according to the richness of the stopes where they work. This is a cheap way of getting ore as far as labor is concerned. But the miners must be constantly watched; otherwise they will leave the mine in bad state. The proportion of ore assigned to the miners is generally bought from them by the mine

owner himself, for various reasons.

Parting.—(1) Any thin interstratified bed of earthy material. (2) A side track or turnout in a haulage road.

Pasilla (Spanish).—Dry silver amalgam.

Pass.—(1) A convenient hole for throwing down ore to a lower level. (2) A passage left in old workings for men to travel in from one level to another.

Pass-By.—A siding in which cars pass one another underground. A turnout. Pass-Into.—When one mineral gradually passes into another without any

sudden change.

Patent Fuel.—Small coal mixed with 8 to 10% of pitch or tar, and compressed by machinery into bricks.

Patented Claim.—A claim to which a patent right has been secured from the government, by compliance with the laws relating to such claims.

Patent Survey.—An accurate survey of a claim by a deputized surveyor as required by law in order to secure a patent right to the claim.

Pavement.—The floor.

Patio (Mexican).—Any paved enclosure more or less surrounded by build-An ore-sorting yard. A floor or yard where argentiferous mud is treated by amalgamation. Pay.—Profitable ore.

Pay Dirt.—That portion of an alluvial deposit that contains gold in payable quantities.

Pay Out.—To slacken or let out rope. Pay Rock—Mineralized rock.

Pay Streak.—Mineralized part of rock. Peach Stone (Cornish).—Chlorite schist.

Pea Coal.—A small size of anthracite coal (see page 434).

Peas.—Small coal about \ to \ in. cube.

Peat.—The decomposed partly carbonized organic matter of bogs, swamps, etc. Pebble Jack.—Zinc blende in small crystals or pebble-like forms is not attached to rock, but is found in clay openings in the rock.

Pee (Derbyshire).—A fragment of lead ore.

Pella, or Plata Pella (Mexican).—Silver amalgam.

Penstock.—See Forebay.

Pent House.—A wooden covering for the protection of sinkers working in a

Pentice.—A few pieces of timber laid as a roof over men's heads, to screen them when working in dangerous places, e.g., at the bottom of shafts. Pepenado (Spanish).—Dressed ore. Pepenar (Mexican).—To sort ore.

Percussion Table.—A kind of jolting table used in separating very fine ores from slimes.

Pestle.—A hard rod for pounding minerals, etc.

Peter Out.—To "peter out" is to thin out, or gradually decrease in thickness. Petlanque (Mexican).-Ruby silver.

Petrifaction.—Organic remains converted into stone.

Pick.—(1) A tool for cutting and holing coal. (2) To dress the sides or face of an excavation with a pick.

Picker. -(1) A small tool used to pull up the wick of a miner's lamp. (2) A person who picks the slate from the coal in an anthracite-coal breaker.

Picking Chute.-A chute in an anthracite breaker along which boys are

Picking Chule.—A chuice in an antiffactic preaser along which copys are stationed to pick the slate from coal.

Picking Tuble.—(1) A flat or slightly inclined platform on which anthracite coal is run to be picked free from slate. (2) A sorting table.

Pico (Mexican).—A striking or sledge hammer.

Picture.—A screen to keep off falling water from men at work.

Picture.—A screen to keep off falling water from men at work.

Picture.—A piece of lead or iron cast into a long iron mold.

Pigs.—Inhering.—Hollow pillows built up of logs of wood laid crosswise for supporting heavy weights. for supporting heavy weights. Pike.—A pick.

Pilar (Mexican).—A pillar of rock or ore left to sustain some portion of the

Pilch (Cornish).—Portion of lode worked by tributers. Pileta (Mexican).—(1) A sump. (2) The basin or pot where melted metal

is collected. Piling.-Long pieces of timber driven into soft ground for the purpose of securing a solid base on which to build any superstructure.

Pillar.—(1) A solid block of coal, etc. varying in area from a few square yards to several acres. (2) Sometimes applied to a single timber support.

Pillar-and-Room.—A system of working coal by which solid blocks of coal are left on either side of the rooms, entries, etc. to support the roof until the rooms are driven up, after which they are drawn out.

Pillar-and-Stall.—See Breast-and-Pillar.

Pillar Roads.-Working roads or inclines in pillars having a range of longwall faces on either side.

Pillion (Cornish).—Metal remaining in slag. Piña (Mexican).—Same as Pella.

Pinch.—A contraction in the vein.

Pinch Out.—When a lode runs out to nothing.

Pinta (Mexican).—The color, weight, grain, etc. of ores, whereby it is possible to form some idea of their richness in the various metals.

Pipe.—An elongated body of mineral. Also the name given to the fossil trunks of trees found in coal veins.

Pipe Clay.-A soft white clay. Piped Air.—Air carried into the working place by pipes or brattices.

Piping.—Undercutting and washing away gravel before the water nozzle.
 Pit.—(1) A shaft. (2) The underground portion of a colliery, including all workings. (3) A gravel pit.

Pit Bank.—The raised ground or platform where the coal is sorted and

screened at the surface.

Pit Bottom.—The portion of a mine immediately around the bottom of a shaft or slope. See Shaft Bottom.

Pitch.—(1) Rise of a seam. (2) Grade of an incline. (3) Inclination.

Pit Coal.—Generally signifies the bituminous varieties of coal.

Pit Frame.—See Head-Frame.

Pit Headman.—The man who has charge at the top of the shaft or slope.

Pitman.—A miner; also, one who looks after the pumps, etc.

Pit Prop.—A piece of timber used as a temporary support for the roof. Pit Rails.—Mine rails for underground roads.

Pit Room.—The extent of underground workings in use or available for use. Pit's Eye.—Pit bottom or entrance into a shaft.
Pit Top.—The mouth of a shaft or slope.

Place.—The portion of coal face allotted to a hewer is spoken of as his "working place," or simply "place."

Placer.—A surface accumulation of mineral in the wash of streams.

Placer Mining.—Surface mining for gold where there is but little depth of

Plan.—(1) The system on which a colliery is worked as Longwall, Pillarand Breast, etc. (2) A map or plan of the colliery showing outside improvements and underground workings. (3) (Mexican) The very lowest working in a mine. Trabajar de Plan.—To work to gain depth.

Plancha (Mexican). - A pig of lead, etc. A plate, thick sheet, or mass of any metal.

Planchera (Mexican).—A mold of sand, earth, or iron, to form pigs of lead.

Plane.—A main road, either level or inclined, along which coal is conveyed

by engine power or gravity.

Plane Table.—A simple surveying instrument by means of which one can

plot on the field.

Planilla (Mexican).—An inclined plane of mason work, wood, etc., on which tailings are spread out, to be concentrated by jets of water, skilfully applied. Planillero (Mexican).—A workman who devotes himself to concentrating

tailings, etc. on the Planillus; always paid by weight, measure, or con-

centrates produced.

Plank Dam.—A water-tight stopping fixed in a heading constructed of timber placed across the passage, one upon another, sidewise, and tightly wedged.

Plank Tubbing.—Shaft lining of planks driven down vertically behind wooden cribs all around the shaft, all joints being tightly wedged, to

keep back the water.

Plant.—The shafts or slope, tunnels, engine houses, railways, machinery, workshops, etc. of a colliery or other mine.

Plat, or Map.—A map of the surface and underground workings, or of either, to draw such a map from survey.

Plata (Spanish).—Silver. Plata Blanca (Mexican).—Native silver.

Plata Blanca (Mexican).—Native silver.

Plata Cornea Amarilia (Spanish).—Odyrite.

Plata Cornea Blanca (Spanish).—Embolite.

Plata Cornea Verde (Spanish).—Embolite.

Plata Wixia (Spanish).—Gid and silver alloy.

Plata Negra (Spanish).—Argentite.

Plata Pasta (Spanish).—Spongy silver bars after retorting.

Plata Verde (Spanish).—Spongy silver plata Verde (Spanish).—Bromyrite.

Plata Verde (Spanish).—Spongy shale in limestone bode. Plate (North of England).—Scaly shale in limestone beds.

Plates.—Metal rails 4 ft. long.

Plenum.—A mode of ventilating a mine or a heading by forcing fresh air

Plomada (Mexican).—A plumb-line or plumb-bob.

Plomb d'Oeuvre (French).—Dressed galena.

Plomillos (Mexican).—Shots of lead found in slags.

Plomo (Spanish).—Lead, galena.

Plugging.—When drift water forces its way through the puddle clay into the shaft, holes are bored through the slabs near the leakage point, and plugs of clay forced into them until the leakage is stopped.

Plumb.—Vertical.

Plummet.—(1) A heavy weight attached to a string or fine copper wire used for determining the verticality of shaft timbering. (2) A plumb-bob for setting a surveying instrument over a point. Plunger.—The solid ram of a force pump working in the plunger case.

Plunger Case. - The pump cylinder or barrel in which the plunger works.

Plush Copper.—Chalcotrichite. Plum (Welsh).—Lead.

Poblar (Mexican).—To set men at work in a mine.

Pocket.—(1) A thickening out of a seam of coal or other mineral over a small area. (2) A hopper-shaped receptacle from which coal or ore is loaded into cars or boats.

Podar (Cornish).—Copper pyrites.

Pole Tools.—Drilling tools used in drilling in the old fashion, with rods, now superseded by the rope-drilling method.

Polroz (Cornish). - Waterwheel pit.

Poling.—Refining metal, when in a molten condition, by stirring it up with a green pole of wood.

Poll Pick.—A pick having the longer end pointed and the shorter end hammer-shaped.

Polvillos (Spanish).—Rich ores or concentrates.

Polvoulla (Spanish) .- Black silver.

Poppet Heads.—The pulley frame or hoisting gear over a shaft.

Poppet (Puppet).—(1) A pulley frame or the head-gear over a shaft.

valve that lifts bodily from its seat instead of being hinged.

Post.—(1) Any upright timber; applied particularly to the timbers used for propping. See Prop. (2) Local term for sandstone. Post stone may be "strong," "framey," "short," or "broken."
 Post-and-Stall.—A system of working coal much the same as Pillar-and-Stall, Post Tertiary.—Strata younger than the Tertiary formation.
 Pot Bottom.—A large boulder in the roof slate, having the appearance of the rounded bottom of a pot, and which easily becomes detached.
 Pot Growan (Cornish).—Decomposed granite.
 Pot Hole.—A circular hole in the rook caused by the action of stones whirled.

Pot Hole.—A circular hole in the rock caused by the action of stones whirled around by the water when the strata was covered by water. They are generally filled with sand and drift.

Power Drill.—A rock drill employing steam, air, or electricity as a motor.

Prian (Cornish).—Soft white clay.

Pricker.—(1) A thin brass rod for making a hole in the stemming when blasting, for the insertion of a fuse. (2) A piece of bent wire by which the size of the flame in a safety lamp is regulated without removing the top of the lamp.

Prill.—(1) An extra-rich stone of ore. (2) A bead of metal.

Prong (English).—The forked end of the bucket-pump rods for attachment to the traveling valve and seat.

Prop.—A wooden or cast-iron temporary support for the roof.

Propping.—The timbering of a mine.

Prospect.—The name given to underground workings whose value has not yet been made manifest. A prospect is to a mine what mineral is to ore.

Prospect Hole.—Any shaft or drift hole put down for the purpose of prospecting the ground. Prospect Tunnel or Entry.—A tunnel or entry driven through barren measures

or a fault to ascertain the character of strata beyond.

Prospecting.—Examining a tract of country in search of minerals.

Prospector.—One engaged in searching for minerals.

Protector Lamp.—A safety lamp whose flame cannot be exposed to the outward atmosphere, as the action of opening the lamp extinguishes the

Prove.—(1) To ascertain, by boring, driving, etc., the position and character of a coal seam, a fault, etc. (2) To examine a mine in search of firedamp, etc., known as "proving the pit."

Proving Hole.—(1) A bore hole driven for prospecting purposes. (2) A small heading driven in to find a bed or vein lost by a dislocation of the contraction of the cont

the strata, or to prove the quality of the mineral in advance of the other workings.

Pudding Machine.—A circular machine for washing pay dirt.

Pudding Rock.—Conglomerate.

Puddle.—(1) Earth well rammed into a trench, etc., to prevent leaking.

(2) A process for converting cast iron into wrought iron.

Pueble (Mexican).—The actual working of a mine; the aggregation of persons employed therein.

Puertas (Mexican).—Massive barren rocks, or "horses," occurring in a vein. Pug Mill.—A mill for preparing clay for bricks, pottery, etc.

Pulley.—(1) The wheel over which a winding rope passes at the top of the head-gear. (2) Small wooden cylinders over which a winding rope is carried on the floor or sides of a plane.

Pulleying.—Overwinding or drawing up a cage into the pulley frame.

Pulp.—Crushed ore, wet or dry.

Pump.—Any mechanism for raising water.

Pump Bob. - See Bob.

Pump Ring.—A flat iron ring that, when lapped with tarred baize or engine

shag, secures the joints of water columns.

Pump Rods.—Heavy timbers by which the motion of the engine is transmitted to the pump. In Cornish and bull pumps, the weight of the rods makes the effective (pumping) stroke, the engine merely lifting the rods on the up stroke.

Pump Slope.—A slope used for pumping machinery

Pump Station.—An enlargement made in the shaft, slope, or gangway, to receive the pump.

Pump Tree. -Cast-iron pipes, generally 9 ft. long, of which the column or set is formed.

to ach-and-Thirl.—A kind of pillar-and-stall system of working.

Punch Prop.—A short timber prop set on the top of a crown tree, or used in holding, as a sprag.

Putty Stones.—Soft pieces of decomposed rock found in placer deposits.

Pyran (Cornish).—See Prian.

Pyrites.—Sulphide of iron.

Pyrometer.—An instrument for measuring high degrees of heat.

Quajado (Spanish).—Dull lead ore.

Quarry.—(1) An open surface excavation for working valuable rocks or minerals. (2) An underground excavation for obtaining stone for stowage or pack walls.

Quartz Bucket.—A bucket for hoisting quartz.

Quaternary.—Post-tertiary period.
Quemadero (Mexican).—A burning place; a retorting furnace for silver or gold amalgam. Quemados (Mexican).—Burnt stuff. Any dark cinder-like mineral encoun-

tered in a vein or mineral deposit, generally manganiferous.

Queme (Mexican).—A roast of ore; the process of roasting ore.

Quick (Adjective).—Soft, running ground; an ore or pay streak is said to be quickening when the associated minerals indicate richer mineral

ahead. Quick (Noun).—(1) Productive. (2) Mercury.
Quicksand.—Soft watery strata easily moved, or readily yielding to pressure.

Quicksilver.—Mercury.

Quillato (Spanish).—Carat. Quitapepena (Mexican).—A watchman that searches the miners as they come out at the mouth of a mine.

Rabban (Cornish).-Yellow dry gossan.

Rabbling.—Stirring up a charge of ore in a reverberatory furnace with specially designed iron rods.

Race.—A channel for conducting water to or from the place where it performs work. The former is termed the headrace, and the latter the tailrace.

Rack (Cornish).—A stationary buddle.

Raff.-The coarse ore after crushing by Cornish rolls.

Raffain (Cornish).-Poor ore.

Raff Wheel.—A revolving wheel with side buckets for elevating the raff. Rafter Timbering.—That in which the timbers appear like roof rafters.

Rag Burning (Cornish).—The first roasting of tin-witts.

Ragging (Cornish). Rough cobbing.

Rag Wheel.—Sprocket wheel. A wheel with teeth or pins that catch into the links of chains.

Rails.—The iron or steel portion of the tramway or railroad.

Rake (Cornish).-(1) A vein. (2) (Derbyshire) Fissure vein crossing strata. Ram.—(1) The plunger of a pump. (2) A device for raising water.
Ramal (Mexican).—A branch vein.

Ramalear (Mexican).—To branch off into various divisions.

Ramble.—Stone of little coherence above a seam that falls readily on the removal of the coal. See Following Stone.

Rance.-A pillar of coal.

Rapper.—A lever with a hammer attached at one end, which signals by striking a plate of metal, when the signaling wire to which it is attached

Rash.—A term used to designate the bottom of a mine when soft and slaty.

Rastrillo (Mexican).—A rake; a stirrer for moving ore in a furnace.
Rastron (Mexican).—A Chilian mill.

Raw Ore.—Not roasted or calcined.

Reacher.—A slim prop reaching from one wall to the other.

Reamer.-An enlarging tool.

Reaming.-Enlarging the diameter of a bore hole.

Receiving Pit.—A shallow pit for containing material run into it.

Red-Ash Coal.—Coal that produces a reddish ash, when burnt.

Red Rab (Cornish).—Red slaty rock.

Reduced.—When a metal is freed from its chemical associate it is said to be reduced to the metallic state. Reduction Works.-Works for reducing metals from their ores.

Reef.—(1) A vein of quartz. (2) Bed rock of alluvial claims.

Reef Drive. - In alluvial mines, drives made in the country rock or reef.

Refining.—The freeing of metals from impurities.

Refractory.—Rebellious ore, not easily treated by ordinary processes.

Refuge Hole.—A place formed in the side of an underground plane in which

a man can take refuge during the passing of a train, or when shots are fired.

Regulator.—A door in a mine, the opening or shutting of which regulates the supply of ventilation to a district of the mine.

Regulus.—See Matte. Relampago, or Relampaguear (Mexican).—The brightening of the silver

button during cupellation. Reliz (Spanish).—Wall of lode.

REF

Rendir (Mexican).—Is when all the silver has been amalgamated in a heap of argentiferous mud on a patio.

Rendrock.-A variety of dynamite.

Repairman.—A workman whose duty it is to repair tracks, doors, brattices, or to reset timbers, etc., under the direction of the foreman.

Repaso-Repasar (Mexican).—The art of mixing up the mud heaps in the patio process of amalgamation by treading them over with horses or mules.

Repos Adero (Mexican).—The bottom of a crucible or pot in an upright smelting furnace.

Rescatadores (Mexican).—Ore buyers.

Reserve.—Mineral already opened up by shafts, winzes, levels, etc., which may be broken at short notice for any emergency.

Reservoir.—An artificially built, dammed, or excavated place for holding a

reserve of water.

Respaldos (Mexican).-The walls enclosing a vein. Respaldo Alto.-The hanging wall. Respaldo Bajo.—The foot-wall.
Rests, Keeps, Wings.—Supports on which a cage rests when the loaded car

is being taken off and the empty one put on.

Resue.—See Stripping. Retort.—(1) A vessel with a long neck, used for distilling the quicksilver

from amalgam. (2) The vessel used in distilling zinc. Return.—The air-course along which the vitiated air of a mine is returned

or conducted back to the upcast shaft. Return Air.—The air that has been passed through the workings.

Reverberatory.—A class of furnaces in which the flame from the fire-grate is made to beat down on the charge in the body of the furnace. Reversed Fault.—See Overlap Fault.

Rib.—The side of a pillar.

Rib-and-Pillar.—A system of working similar to Pillar-and-Stall.

Ribbon.—A line of bedding or a thin bed appearing on the cleavage surface and sometimes of a different color.

Rick.—Open heap in which coal is coked.

Rick.—Open neap in which coal is coked.

Ridding.—Clearing away fallen stone and débris.

Ridding.—Clearing away fallen stone and débris.

Ridding.—An oblong frame holding iron bars parallel to each other, used for sifting material that is thrown against it.

Ride, Ridning.—To be conveyed on a cage or mine car.

Rider.—(1) A guide frame for steadying a sinking bucket. (2) Boys that ride on trips on mechanical haulage roads. (3) A thin seam of coal overlying a thicker one.

Riffle. or Ripple.—Crosspieces placed on the bottom of a sluice to save gold:

or grooves cut across inclined tables.

Right Shore.—The right shore of a river is on the right hand when descend-

ing the river.

Rill.—The coarse ore at the periphery of a pile. Rim Rock.—Bed rock forming a boundary to gravel deposit.

Ring.—(1) A complete circle of tubbing plates placed round a circular shaft.
 (2) Troughs placed in shafts to catch the falling water, and so arranged

as to convey it to a certain point.

Ripping.—Removing stone from its natural position above the seam.

Riscos (Mexican).—Sharp and precipitous rocks; amorphous quartz found in veins or outcrops.

Rise.—The inclination of the strata, when looking up the pitch. Rise Workings.—Underground workings carried on to the rise or high side of the shaft.

River Mining.—Working beds of existing rivers by deflecting their course or by dredging.

Road.—(1) Any underground passageway or gallery. (2) The iron rails, etc. of underground roads.

Roasting.—Heating ores at a temperature sufficient to cause a chemical change, but not enough to smelt them.

Rob.—To cut away or reduce the size of pillars of coal.

Robbing.—The taking of mineral from pillars.

Robbing an Entry.—See Drawing an Entry.

Rock.—A mixture of different minerals in varying proportions.

Rock Breaker.—A machine for reducing ore in size by crunching it between powerful jaws.

Rock Chute.—See Slate Chute.

Rock Drill.—A rock-boring machine worked by hand, compressed air, steam,

ROA

or electrical power.

Rocker.-See Cradle.

Rock Fault.—A replacement of a coal seam over greater or less area, by some other rock, usually sandstone. Rodding.-The operation of fixing or repairing wooden eye guides in

shafts. Roll.—An inequality in the roof or floor of a mine.

Roller.-A small steel, iron, or wooden wheel or cylinder upon which the hauling rope is carried just above the floor.

Rolleyway .- A main haulage road.

Rolling Ground .- When the surface is much varied by many small hills and valleys.

Rolls.-Cast-iron cylinders, either plain or fitted with steel teeth, used to break coal and other materials into various sizes.

Roof.—The top of any subterranean passage.

Room.—Synonymous with Breast. Room-and-Rance.—A system of working coal similar to Pillar-and-Stall.

Rope Roll.—The drum of a winding engine.
Rosiclara (Spanish).—Ruby silver ore.
Roughs (Cornish).—Second quality tin sands.

Round Coal.—Coal in large lumps, either hand-picked, or, after passing over screens, to take out the small.

Royalty.—The price paid per ton to the owner of mineral land by the lessee. Rubbing Surface.—The total area of a given length of airway: that is, the area of top, bottom, and sides added together, or the perimeter multiplied by the length.

Rubble.—Coarse pieces of rock.

Rumbo (Mexican).—The course or direction of a vein.

Run.-(1) The sliding and crushing of pillars of coal. (2) The length of a lease or tract on the strike of the seam.

Run Coal .- Soft bituminous coal.

Rung, Rundle, or Round.—A step or cross-bar of a ladder.
Runner.—A man or boy whose duty it is to run mine cars by gravity from working places to the gangway.

Running Lift.—A sinking set of pumps constructed to lengthen or shorten at will, by means of a sliding or telescoping wind bore.

Rush.—An old-fashioned way of exploding blasts by filling a hollow stalk

with slow powder and then igniting it.

Rush Gold.—Gold coated with oxide of iron or manganese.

Rush Together.—See Caved In. Rusty.—Stained by iron oxide.

Sees (Mexican).—A bagful of ore. A mine is said to be de buena saca when it has large quantities of ore easy to get out.

Saddle.—An anticlinal, a hogback.

Saddleback.—A depression in the strata. See Roll.

Saddle Reef.—A reef having the form of an inverted \forall . Safety Cage.—A cage fitted with an apparatus for arresting its motion in the shaft in case the rope breaks.

Safety Car .- See Barney.

Safety Catches.—Appliances fitted to cages, to make them safety cages. Safety Door.—A strongly constructed door, hinged to the roof, and always kept open and hung near to the main door, for immediate use when

main door is damaged by an explosion or otherwise. Safety Fuse.-A cord with slow-burning powder in the center for exploding

charged blast holes.

Safety Lamp.—A miner's lamp in which the flame is protected in such a manner that an explosive mixture of air and firedamp can be detected by the mixture burning inside the gauze.

Sag.—A depression, e.g., in ropes, ranges of mountains, etc. Sagre, or Seggar.—A local term for fireclay, often forming the floor (or thill) of coal seams.

Salting .- (1) Changing the value of the ore in a mine or of ore samples before they have been assayed, so that the assay will show much higher values than it should. (2) Sprinkling salt on the floors of underground passages in very dry mines, in order to lay the dust.

Sampler.—(1) An instrument or apparatus for taking samples. (2) One whose

duty it is to select the samples for an assay, or to prepare the mineral to be assayed, by grinding and sampling.

Sampling Works.—Works for sampling and determining the values obtained in ores; where ores are bought and sold.

Samson Post.—An upright supporting the working beam that communicates oscillatory motion to pump or drill rod.

Sand Bag.—A bag filled with sand for preventing a washout by obstructing

the flow. Sand Pump.-A sludger; a cylinder provided with a stem (or other) valve. lowered into a drill hole to remove the pulverized rock.

Scaffolding.—Incrustations on the inside of a blast furnace.

Scale.—(1) A small portion of the ventilating current in a mine passing through a certain size of aperture. (2) The rate of wages to be paid. which varies under certain contingencies.

Scale Door.—See Regulator.

Scallon.—To hew coal without kirving or nicking or shot firing.

Schist.—Crystalline or metamorphic rocks having a slaty structure. Schute.—See Chute.

Scissors Fault.—A fault of dislocation, in which two beds are thrown so as to cross each other.

Scoop.-A large-sized shovel with a scoop-shaped blade.

Scoria.—Ashes.

Scorifler .- A small dish used in assaying.

Scovan (Cornish).—A tin lode showing no gossan at surface.

Scove (Cornish).—Purest tin ore.
Scramming.—Cleaning up small bodies or patches of ore left in the ordinary process of mining.

Scraper.—(1) A tool for cleaning the dust out of the bore hole. (2) A

mechanical contrivance used at colleries to scrape the culm or slack along a trough to the place of deposit.

Scrapper.—A local name given to parties that pick up the ore left on dumps. Screen.—(1) A mechanical apparatus for sizing materials. (2) A cloth brattice or curtain hung across a road in a mine, to direct the ventilation.

Scrin (Derbyshire).—A small vein.
Scrowl (Cornish).—Loose ore where a vein is crossed.

Sculping.—Fracturing the slate along the grain, i. e., across the cleavage.

Scupper Nails.-Nails with broad heads, for nailing down canvas, etc.

Sea Coal.—That which is transported by sea. Sealing.—Shutting off all air from a mine or a part of a mine by stoppings. Seam.—(1) Synonymous with Bed, Vein, etc. (2) (Cornish) A horse load

of ore. Seam-Out.—A term applied to a shot or blast that has simply blown out a softer stratum of the deposit in which it was placed, without dislodging the

other strata or layers of the seam. Second Outlet (Second Opening) .- A passageway out of a mine, for use in case

of accident to the main outlet. Seconds.—The second-class ore of a mine that requires dressing.

Second Working.—The operation of getting or working out the pillars formed

by the first working. Section.—(1) A vertical or horizontal exposure of strata. (2) A drawing or sketch representing the rock strata as cut by a vertical or a horizontal

plane. Sedimentary Rocks.-Rocks formed from deposits of sediment by wind or water.

Seedbag.—A water-tight packing of flaxseed around the tube of a drill hole. to prevent the influx into the hole of water from above.

Surgentions.—Detached portions of veins in place.

- Self-Acting Plane.—An inclined plane upon which the weight or force of gravity acting on the full cars is sufficient to overcome the resistance of the emptice; in other words, the full car, running down, pulls the other car up.
- Self-Detaching Hook.—A self-acting hook for setting free a hoisting rope in case of overwinding.

Self-Feeders.—Automatic appliances for feeding ore-dressing machines.

Selvage.—The clay seam on the walls of veins; gouge.

Separation Doors.—The main doors at or near the shaft or slope bottom,

which separate the intake from the return airways.

Separation Valve.—A massive cast-iron plate suspended from the roof of a return airway through which all the return air of a separate district flows, allowing the air to always flow past or underneath it; but in the event of an explosion of gas, the force of the blast closes it against its frame or seating, and prevents a communication with other districts. The blast being over, the weight of the valve allows it to return to its normal position.

Set.—To fix in place a prop or sprag.
Set Hammer.—The flat-faced hammer held on hot iron by a blacksmith when

shaping or smoothing a surface by aid of his striker's sledge.

Set of Timber.—The timbers which compose any framing, whether used in a shaft, slope, level, or gangway. Thus, the four pieces forming a single course in the curbing of a shaft, or the three or four pieces forming the legs and collar, and sometimes the sill of an entry framing are together called a set of timber, or timber set.

Shackle.—A U-shaped link in a chain closed by a pin; when the latter is withdrawn the chain is severed at that point.

Shadd (Cornish).—Rounded fragments of ore overlying a vein.
Shaft.—A vertical or highly inclined pit or hole made through strata, through which the product of the mine is hoisted, and through which the ventilation is passed either into or out of the mine. A shaft sunk from one seam to another is called a "blind shaft."

Shaft Pillar.—Solid material left unworked beneath buildings and around

the shaft, to support them against subsidence.

Shaking Tuble.—An inclined table for concentrating fine grains of ore, which is rapidly shaken by a short motion

Shale.—(1) Strictly speaking, all argillaceous strata that split up or peel off in thin laminæ. (2) A laminated and stratified sedimentary deposit of

clay, often impregnated with bituminous matter.

Shank.—The body portion of any tool, up from its cutting edge or bit.

Shearing.—Cutting a vertical groove in a coal face or breast. The cutting of a "fast end" of coal.

Shear Legs.—A high wooden frame placed over an engine or pumping shaft fitted with small pulleys and rope for lifting heavy weights.

Shears, or Sheers (English).—Two tall poles, with their feet some distance apart and their tops fastened together, for supporting hoisting tackle.

Shear Zone.—Hogback.

Sheave.—A wheel with a grooved circumference over which a rope is turned either for the transmission of power or for winding or hauling.

Sheel Pump.—See Sludger.

Sheets.—Coarse cloth curtains or screens for directing the ventilating current

underground.

Shelly.—A name applied to coal that has been so crushed and fractured that it easily breaks up into small pieces. The term is also applied to a laminated roof that sounds hollow and breaks into thin layers of slate or

Shet (Staffordshire).—Fallen roof of coal mine.

Sheth.—An old term denoting a district of about eight or nine adjacent bords.

Thus, a "sheth of bords," or a "sheth of pillars."

Shift.—(1) The number of hours worked without change. (2) A gang or

force of workmen employed at one time upon any work, as the day shift, or the night shift.

Shoad (Cornish).-See Shadd.

Shoading (Cornish).—Prospecting. Shoe.—(1) A steel or iron guide piece fixed to the ends or sides of cages, to fit or run on the conductors. (2) The upper working face of a stamp or grinding pan. (3) The lower capping of any post or pile, to protect its end while driving. (4) A wooden or sheet-iron frame or muff arranged SIN

at the bottom of a shaft while sinking through quicksand, to prevent inflow of sand while inserting the shaft lining.

Shoot, Chute, Shute.—(1) A run of rich material in a vein. (2) An incli or vertical trough or pipe for conveying materials from a higher lower level.

Shoot.—To break rock or coal by means of explosives.

Shooting.—Blasting in a mine.

Shore (English).—A studdle or thrusting stay.

Shore U_{D_1} —To stay, prop up, or support by braces. Shot.—(1) A charge or blast. (2) The firing of a blast. (3) Injured by

blast.

Shot Firer.—See Shot Lighter.
Shot Hole.—The bore hole in which an explosive substance is placed.

blasting.

Shot Lighter, or Shot Firer.—A man specially appointed by the manager the mine to fire off every shot in a certain district, if after he examined the immediate neighborhood of the shot, he finds it free free gas, and otherwise safe.

Shotty Gold.—Granular pieces like shot.

Show.—When the flame of a safety lamp becomes elongated or unsteady owing to the presence of firedamp in the air, it is said to show.

Showing.—The first appearance of float, indicating the approach to an out

cropping vein or seam. Blossom. Shroud.—A housing or jacket. Shute.—See Chute, Shoot, and Schute.

Shutter.—(1) A movable sliding door, fitted within the outer casing of Guibal or other closed fan, for regulating the size of the opening from the fan, to suit the ventilation and economical working of the machine. (2) A slide covering the opening in a door or brattice, and forming a regulator for the proportionate division of the air-current between two or more districts of a mine.

Sickening.—A coating of impurities on quicksilver that retards amalgama-

tion or the coalescence of the globules of quicksilver.

Siddle.—Inclination.

Side.—(1) The more or less vertical face or wall of coal or goaf forming one side of an underground working place. (2) Rib. (3) A district.

Side Chain.—A chain hooked on to the sides of cars running on an incline or

along a gangway, to keep the cars together in case the coupling breaks. Sidelong Reef.—An overhanging wall of bed rock in alluvial formations

running parallel with the course of the gutter; generally only on one side of it. Siding.—A short piece of track parallel to the main track, to serve as a

passing place. Siding Over.—A short road driven in a pillar in a headwise direction.

Sight.—(1) A bearing or angle taken with a compass or transit when making

a survey. (2) Any established point of a survey. Sights.—Bobs or weighted strings hung from two or more established points

in the roof of a room or entry, to give direction to the men driving the entry or room.

Sill.—(1) The floor piece of a timber set, or that on which the track rests:
the base of any framing or structure. (2) The floor of a seam.

Silver.-(1) A certain white ductile and valuable metal. (2) Short for quicksilver. Sing.—The noise made by a feeder of gas issuing from the coal.

Singing Coal.—Coal from which gas is issuing with a hissing sound.

Singing Lamp.—A safety lamp, which, when placed in an atmosphere of explosive gas, gives out a peculiar sound or note, the strength of the note varying in proportion to the percentage of firedamp present.

Single-Entry System.—A system of opening a mine by driving a single entry only, in place of a pair of entries. The air-current returns along the face of the rooms, which must be kept open.

Single-Intake Fan.—A ventilating fan that takes or receives its air upon one side only.

Single-Rope Haulage.—A system of underground haulage in which a single rope is used, the empty trip running in by gravity. This is engine-plane haulage.

Sink.—To excavate a shaft or slope; to bore or put down a bore hole.

Sinker.—A man who works at the bottom of a shaft or face of a slope during

the course of sinking.

Sinker Bar.—In rope drilling, a heavy bar attached above the jars, to give force to the up stroke, so as to dislodge the bit in the hole.

Sinking.—The process of excavating a shaft or slope or boring a hole.

Siphon.—A simple, effective, and economical mode of conveying water over a hill whose height is not greater than what the atmospheric pressure will raise the water. Its form is that of an iron pipe, bent like an inverted U; the vertical height between the surface of the water in the upper basin and the top of the hill is called the lift of the siphon; while the vertical height between the surfaces of the water in the upper and lower basins is called the fall of the siphon.

Sizing.—To sort minerals into sizes.

Skew Back.—The beveled stone from which an arch springs, and upon which it rests.

Skids.—Slides upon which heavy bodies are slid from place to place.

Skimpings (Cornish).—The poorest ore skimmed off the jigger.

Skip.—(1) A mine car. (2) A car for hoisting out of a slope. (3) A thin slice taken off from a breast or pillar or rib along its entire length or part of its length.

Skirting.—Road opened up or driven next a fall of stone, or an old fallen place. Skit (Cornish).—A pump.

Slab.—Split pieces of timber from 2 in. to 3 in. thick, 4 ft. to 6 ft. long, and 7 in. to 14 in. wide, placed behind sets or frames of timber in shafts or levels.

Stack.—(1) Fine coal that will pass through the smallest sized screen. The fine coal and dust resulting from the handling of coal, and the disintegration of soft coal. (2) The process by which soft coal disintegrates when exposed to the air and weather.

Slag.—The liquid refuse from a smelting operation, which floats on top of

the metal.

Slant.—(1) An underground roadway driven at an angle between the full rise or dip of the seam and the strike or level. (2) Any inclined road in a seam.

Slant Chutes.—Chutes driven diagonally across a pillar, to connect a breast

manway with a manway chute.

Slate.—(1) A hardened clay having a peculiar cleavage. (2) About coal mines, slate is any shale accompanying the coal, also sometimes applied to bony coal. Slate Picker.-(1) A man or boy that picks the slate or bony coal from

anthracite coal. (2) A mechanical contrivance for separating slate and State Chute.—(1) A chute for conveying state or bony coal to a pocket from

which it is loaded into "dumpers." (2) A chute driven through slate.

Sleck (Derbyshire).—Mud in a mine.
Sled.—A drag used to convey coal along the face to the road head where it is

loaded, or to the chute.

Sledge.—A heavy double-handed hammer.

Sleeper (English).—The foundation pieces or cross-ties on which rails rest.

Sleeping Table (Cornish).—A buddle.

Sleeve.—A hollow cylinder fitting over two pieces, to hold them together. Slickensides.—Polished surfaces of vein walls.

Slide.-Loose deposit covering the outcrop of a seam.

Slides.—See Guides.

Sliding Scale.—A mode of regulating the wages paid workingmen by taking as a basis for calculation the market price of coal, the wages rising and falling with the state of trade.

Sliding Wind Bore (English).—The bottom pipe or suction piece of a sinking set of pumps having a lining made to slide like a telescope within it, to give length without altering the adjustment of the whole column

of pipes.

Slime, Sludge.—(1) The pulp or fine mud from a mill or from a drill hole. (2) Silt containing a very fine ore, which passes off in the water from

the jigs.

Slings.—Pieces of ropes or chains to be put around stones, etc. for raising them.

Stip.-(1) A fault. (2) A smooth joint or crack where the strata have movéd upon each other.

Stip Cleavage.-Microscopic folding and fracture accompanied by slippage quarrymen's "false cleavage."

Slit.—A short heading put through to connect two other headings.

Slitter.—See Pick.

Slope.—A plane or inclined roadway, usually driven in the seam from the surface. A rock slope is a slope driven across the strata, to connect two seams; or a slope opening driven from the surface, to reach a seam below that does not outcrop at an accessible point.

Sludge.-See Slime.

Sludger, Sludge Pump.—A cylinder having an upward opening valve at the bottom, which is lowered into a bore hole, to pump out the sludge or fine rock resulting from drillings.

Sluice.—(1) A long channel in rock or built of timber, with checks to catch

gold. (2) Any overflow channel.

Sluice Box.—A trough with ripples or false bottom for catching gold.

Sluice Head, or Head (Australia and New Zealand).—A supply of 1 cu. ft. of

water per second, regardless of the head, pressure, or size of orifice.

Sluicing.—Ground sluicing is working gravel by excavating with pick and shovel, and washing the debris in trenches with water not under pressure.

Sturry (North of Wales).—Half-smelted ore. Small.—See Slack.

Smeddum.-Lead-ore dust.

Smelling.—Method of extracting a precious metal from its ores.

Smift, Snift.—A bit of touch paper, touch wood, etc. attached by a bit of clay or grease to the outside end of the train of gunpowder when blasting

Smittem.—Fine gravel-like ore, occurring free in mud openings, or derived

from the breaking of the ore in blasting.

Smut (Staffordshire).—Soft, bad coal.

Snore, Snore Piece.—The hole in the lower part of a sinking or Cornish pump. through which water enters.

Soapstone.—A term incorrectly applied by the miner to any soft, unctuous

Socabon (Mexican).-A mining tunnel; an adit. Socavon á hilo de reta.-A drift tunnel. Socavon crucero.-A crosscut tunnel or adit. Socket.—(1) The innermost end of a shot hole, not blown away after firing.

(2) A wrought-iron contrivance by means of which a wire rope is securely attached to a chain or block.

Sole, Sole Plate.—A piece of timber set underneath a prop.

Sollar.—A wooden platform fixed in a shaft, for the ladders to rest on.

Souter.—A wooden piatform fixed in a shaft, for the ladders to rest on.

Sonder (Mexican).—To bore for prospecting purposes.

Sonder (Mexican).—A boring for prospecting purposes.

Soplete (Mexican).—A blowpipe. Ensaye al Soplete.—A blowpipe assay.

Sorting.—Separating valuable from worthless material.

Sounding.—(1) Knocking on a roof to see whether it is sound or safe to work under. (2) Rapping on a pillar so that a person on the other side of it may be signaled to, or to enable him to estimate its width.

Soun—(1). A tool used for sharmening drills. (2) Lyng darpating at the bestom

Sow.—(1) A tool used for sharpening drills. (2) Iron deposits at the bottom of furnaces.

Spall.—To break up rocks with a large hammer, for hand sorting.

Spalls.—The chips and other waste material cut from a block of stone in process of dressing.

Spar.—A name given to certain white quartz-like minerals, e. g., calcspar. feldspar, fluorspar. Spears.—Pump-rods.

Specimen.—A picked piece of mineral.

Speiss.—A basic arsenide or antimonide of iron, often containing nickel. cobalt, lead, bismuth, copper, etc., having a metallic luster of high specific gravity and a strong tendency toward crystallization.

Speller.—The commercial name for zinc.

Spent Shot.—A blast hole that has been fired, but has not done its work. Spew.—The extension of mineral matter on the surface, past the ordinary limits of the lode.

Spiders.—See Drum Rings.

Spiegeleisen.—Manganiferous white cast iron.

Spiking Curbs.—A light ring of wood to which planks are spiked when plank tubbing is used.

Spiles (Cornish).—A temporary lagging driven ahead on levels in loose ground. Short pieces of planking sharpened flatways, and used for driving into watery strata as sheath piling to assist in checking the flow; used much in sinking through quicksands.

Spiling.—A process of timbering through soft ground.

Spiral Drum.—See Conical Drum.

Splint, or Splent.—A laminated, coarse, inferior, dull-looking, hard coal, producing much white ash, intermediate between cannel and bituminous coal.

Split.—(1) To divide an air-current into two or more separate currents. (2) Any division or branch of the ventilating current. (3) The workings ventilated by that branch. (4) Any member of a coal bed split by thick partings into two or more seams. (5) A bench separated by a considerable interval from the other benches of a coal bed.

Spoil.—Débris from a coal mine.

Spoon.—A slender iron rod with a cup-shaped projection at right angles to the rod, used for scraping drillings out of a bore hole.

Spout.—A short underground passage connecting a main road with an air-

Sprag.—(1) A short wooden prop set in a slanting position for keeping up the coal during the operation of holing. (2) A short round piece of hard wood, pointed at both ends, to act as a brake when placed between the spokes of mine-car wheels. (3) The horizontal member of a square set of timber running longitudinally with the deposit.
Spragger.—One who attends to the spragging of cars.

Sprag Road.—A mine road having such a sharp grade that sprags are needed to control the speed of the car.

Spreader.—A timber stretched across a shaft or stope.

Spring Beams.—Two short parallel timber beams, built with a Cornish pumping engine house, nearly on a level with the engine beam, for catching the beam, etc., and preventing a smash in case of a breakdown.

Spring Latch.—The latch or tongue of an automatic switch, operated by a

spring pole at the side of the track.

Spring Pole.—An elastic wooden pole from which boring rods are suspended.

Used also to operate a spring latch. Sprocket Wheel (English).—Rag wheel. A wheel with teeth or pins which catch in the links of a chain.

Spud, Spad.—A horseshoe nail with a hole in the head, for driving into the mine timbers, or into a wooden plug fitted into the roof, to mark a surveying station.

Spur.—(1) A short ridge or offsetting pointed branch from a main ridge or mountain. (2) A short branch or feeder from the main lode of a vein.
Square Set.—A variety of timbering for large excavations.

Squat (Cornish).-Tin ore mixed with spar.

Squeeze.—See Creep.

Squib.—A straw, rush, paper, or quill tube filled with a priming of gun-powder, with a slow match on one end.

Stage .- A platform on which mine cars stand.

Staging.—A temporary flooring or scaffold, or platform.

Stage Pumping.—Draining a mine by means of two or more pumps placed at different levels, each of which raises the water to the next pump above, or to the surface.

Stage Working.—A system of working minerals by removing the strata above the beds, after which the various beds are removed in steps or stages.

Stalactiles.-Icicle-shaped formations of mineral matter depending from roof strata.

Stalagmites.—Accumulations of mineral matter that form on the floor, caused by the continual dripping of water impregnated with mineral matter. Stall.—A narrow breast, or chamber.

Stall Gate.—A road along which the mineral worked in a stall is conveyed to the main road.

Stamp Mill, Stamps.—Machine for crushing ore.

Stanction.—A vertical prop or strut.
Standage.—Pump reservoir.
Standing.—Not at work, not going forwards, idle.

Standing Gas.—A body of firedamp known to exist in a mine, but not in circulation; sometimes fenced off

Standing Sett (English).—A fixed lift of pumps in a sinking set.

STA

Stannary.-Tin works. Staple.—(1) A shallow pit within a mine. (2) An underground shaft. Starter.—A man who ascends a chute to the battery and starts the coal to

running.

Starved (English).—When a pump is choked at the brass holes. Station.—A plat or convenient resting place in a shaft or level.

Stave.-A ladder step.

Stay (English).—Props, struts, or ties for keeping anything in its place.

Steamboat Coal.—In anthracite only, coal small enough to pass through bars

set 6 to 8 in. apart, but too large to pass through bars from 31 to 5 in. Comparatively few collieries make steamboat coal except to fill special contracts or orders.

Steam Coal.-A hard, free-burning, non-caking coal.

Steam Jet .- A system of ventilating a mine by means of a number of jets of steam, at high pressure, kept constantly blowing off from a series of pipes

in the bottom of the upcast shaft.

Steel Mill.—An apparatus for obtaining light in a flery mine. It consisted of a revolving steel wheel, to which a piece of flint was held, to produce

sparking. Steel Needle. -An instrument used in preparing blasting holes, before the safety fuse was invented.

Steening, or Steining.—The brick or stone lining of a shaft.

Stemmer.—A copper or wooden bar used for stemming.

Stemming.—(1) Fine shale or dirt put into a shot hole after the powder, and

rammed hard. (2) Tamping a shot.

Step (English).—(1) The cavity in a piece for receiving the pivot of an upright shaft, or the end of an upright piece. (2) The shearing in a coal face.

Stint.—The amount of work to be done by a man in a specified time.

Stobb.—A long steel wedge used in bringing down coal after it has been Stockwork.—A rock run through with a number of small veins close

together, the whole of which has to be worked when mining such deposits. Stomp.—A short wooden plug fixed in the roof of a level, to serve as a bench

mark for surveys.

Stone Coal.—Anthracite; also other hard varieties of coal.

Stone Head.—A heading or gangway driven in stone. A tunnel.

Stone Tubbing.—Water-tight stone walling of a shaft cemented at the

back.

Stook.—A pillar of coal about 4 yd. square, being the last portion of a full-sized pillar to be worked away in bord-and-pillar workings. Stook-and-Feather.—A wedge for breaking down coal, worked by hydraulic

power, the pressure being applied at the extreme inner end of the drilled hole.

Stoop.—A pillar of coal.

Stoop-and-Room.—A system of working coal very similar to pillar-and-stall. Stop.—Any cleat or beam to check the descent of a cage, car, pump rods, etc. Stope.—(1) To excavate mineral in a series of steps. (2) A place in a mine

that is worked by stoping. Stoping .- Working out ore between two levels or on the surface, by stopes or

steps. Stoping Overhand.—Mining a stope upwards, the flight of steps being inverted. Stoping Underhand.—Mining a stope downwards in such a series that it presents the appearance of a flight of steps.

Stopping.—An air-tight wall built across any passageway in a mine.

Stove Coal.—In anthracite only; two sizes of stove coal are made, large and small: large stove, known as No. 3, passes through a 2½" to 2" mesh and over a 1½" to 1½" mesh; small stove, known as No. 4, passes through a 1\'' to 1\'' mesh and over a 1\'' to 1'' mesh. Only one size of stove coal is now usually made. It passes through a 2" square mesh and over 1\'' square mesh.

Stove Up, or Stoved.—Upset. When a rod of iron heated at one end is hammered endwise the diameter of that end is enlarged, and it is said to be upset.

Stow .- To pack away rubbish into goaves or old workings.

Stowce.-(1) Windlass. (2) Landmarks. Stowing.—The debris of a vein thrown back of a miner and which supports the roof or hanging wall of the excavation.

Straight Ends and Walls.—A system of working coal somewhat similar to bord-and-pillar. Straight ends are headings from 4 ft. 6 in. to 6 ft. in width. Walls are pillars 30 ft. wide.

Straight Work.—A system of getting coal by headings or narrow work.

Strake.—A slightly inclined table for separating heavier minerals from lighter ones.

Stratification.—Arrangement in layers.

Stratum (plural, strata).—A layer or bed of rocks, or other deposit.

Streak.—The color of the mark made when a mineral is scratched against a

white surface.

Strett.—The system of getting coal by headings or narrow work. Bord-and-Pillar.

Strike (of a seam or vein).—The intersection of an inclined seam or a vein with a horizontal plane. A level course in the seam. The direction of strike is always at right angles to the direction of the dip of the seam.

Strike Joints.—Joints or cleavages that are parallel to the strike of the seam. Striking Deal.—Planks fixed in a sloping direction just within the mouth of

a shaft, to guide the tub to the surface.

Stringer (English).—Any longitudinal timber or beam.

Stringpump.—A system of pumping whereby the motion of the engine is transmitted to the pump by timbers or stringers bolted together.

String Rods.—A line of surface rods connected rigidly for the transmission of power; used for operating small pumps in adjoining shafts from a

central station.

Strip.—(1) To remove the overlying strata of a bed or vein. (2) Mining a deposit by first taking off the overlying material.
Strut (English).—A prop to sustain compression, whether vertical or inclined.
Struve Ventitator.—A pneumatic ventilating apparatus consisting of two vessel-like gas holders, which are moved up and down in a tank of water. By this means, the air is sucked out of the mine as required.
Studdle.—A piece of squared timber placed vertically between two sets of timber in a set.

timber in a shaft.

Stull.—A post for supporting the wall or roof in a mine; a prop timber. Stump.—The pillar between the gangway and each room turned off the gang-

way. Sometimes the entry pillars are called stumps. Stumping.—A kind of pillar-and-stall plan of getting coal.

Stup.—Powdered coke or coal mixed with clay. Sturt.—A tribute bargain profitable to the miner.

Stuttle, or Sprag.—The horizontal member of a square set of timber running longitudinally with the deposit.

Stythe.—Carbonic-acid gas (blackdamp).

Sucker Rod .- The pump rod of an oil or artesian well.

Suction Pump (English).—A pump wherein, by the movement of the piston, water is drawn up into the vacuum caused.

Sulphur.—(1) One of the elements. (2) Iron pyrites. Sulphuret.—See Sulphide.

Sulphide.—A combination of sulphur and a base.

Sump, or Sumpt .- A catch basin into which the drainage of a mine flows and from which it is pumped to the surface.

Surface Deposits.—Those that are exposed and can be mined from the surface. Swab Stick.—A short wooden rod, bruised into a kind of stumpy brush at one end, for cleaning out a drill hole.

Swally, or Swelly.—A trough, or syncline, in a coal seam.
Swamp.—A depression or natural hollow in a seam. A basin.
Sweeping Tuble.—A stationary buddle.
Sweet.—Free from deleterious gases.

Sweet Roast.—To roast dead or completely.

Swing.—The arc or curve described by the point of an instrument, such as a pick or hammer, when being used.

Swinging Plate. - Amalgamated copper plates hung in sluices, to catch float

gold.

Switch.—(1) The movable tongue or rail by which a train is diverted from

20 The innetion of two tracks. (3) A movable arm for changing the course of an electrical current.

Switchboard.—A board where several electrical wires terminate, and where, by means of switches, connection may be established between any of these wires and the main wire.

Swither.—A crevice branching from a main-lead lode.

Synclinal Axis.—The line or course of a syncline.

Syncline.—The point or axis of a basin toward which the strata upon either side dip. An inverted anticline. A basin.

Tackle (English).—(1) Ropes, chain, detaching hooks, cages, and all other apparatus for raising coal or ore in shafts. (2) Any rope for hoisting, as a tackle rope, block and tackle, etc.

Tahona (Mexican).—An arrastre moved by water-power. Tahonero.—The man in charge of the tahona.

Tail-Back.—When the firedamp ignites and the flame is elongated or creeps backwards against the current of air, it is said to tail-back.

Tailing.-The blossom; the outcrop or smut.

Thilings.—The detritus from reduction or gold-washing machinery.
Thil-Pipe.—The suction pipe of a pump.
Thilinge.—The channel along which water flows after it has done its work. Tail-Rope.—(1) In a tail-rope system of haulage, the rope that is used to draw the empties back into the mine. (2) A wire rope attached beneath

cages, as a balance.

Tail-Rope System of Haulage.—A haulage system in which the full trip is drawn out by the main rope, and the empty trip is drawn in by the tail-rope, these ropes being attached to the opposite ends of the trip (see page 400).
Tail-Sheave.—The sheave at the inbye end of any haulage system. See Turn

Pulley.

to the Air.—(1) To measure the ventilating current. (2) Applied to a ventilating fan as working well, or working poorly. Take the

Taladro (Mexican).—A drill for mechanical or mining purposes. Taladrar.-

To bore or drill.

Tally.—(1) A mark or number placed by the miner on every car of coal sent out of his place, usually a tin ticket. By counting these, a tally is made of all the cars of coal he sends out. (2) Any numbering, or counting, or memorandum, as a tally sheet.

Tamp.—To fill a bore hole, after inserting the charge, with some substance which is rammed hard as it is put into the hole. Vertical holes are often

tamped with water, when blasting with dynamite.

Tamping.—The process of stemming or filling a bore hole.

Tamping Bar.-A copper-tipped bar, for ramming the tamping or stem-

Tanates (Mexican).—Leather, hide, or jute bags, to carry ore or waste rock within or out of a mine. Tanatero.—A laborer or bag carrier.

Tap.—(1) To cut or bore into old workings, for the purpose of liberating accumulations of gas or water. (2) To pierce or open any gas or water feeder. (3) To win coal in a new district.

Tapextle (Mexican).—A working platform or stage built up in a stope or any-

where in a mine; a landing place between two flights of ladders.

Teem .- To pour or tip.

Teeming Trough.—A trough into which the water from a mine is pumped. Telegraph.—A sheet-iron trough-shaped chute, for conveying coal or slate from the screens to the pockets, or boilers.

Tellurides.—Ores of the precious metals (chiefly gold) containing tellurium.

Temesquitate (Mexican).—The earthy part of ground-up ore.
Temper.—(1) To change the hardness of metals by first heating and then plunging them into water, oil, etc. (2) To mix mortar, or to prepare clay for bricks, etc.

Tempering.—The act of reheating and properly cooling a bar of metal to any

desired degree of hardness.

Temper Screw. In rope drilling, a screw for gradually lowering the clamped (upper) end of the rope as the hole is deepened.

Tenon.—A projecting tongue fitting into a corresponding cavity called a mortise.

Tentadura (Mexican).—An assay made in a horn spoon, an earthen saucer. or in a wide and shallow vessel of any kind, to ascertain the amount of amalgam present in a sample of argentiferous mud from an amalgamating patio. Any assay made by washing so as to concentrate the metallic portions of any mineral, and to cause the earthy portions to be floated off.

Tepetate (Mexican).—Any rock or earth found in a mine, which does not

contain the metal sought for.

Tequio (Mexican).—A task set for a drillman or for any laborer in a mine, to be regarded as a day's work.

Terrace.—A raised level bank, such as river terraces, lake terraces, etc.

Terrero (Mexican).—The dump of a mine.

Test.—(1) A trial of an engine, fan, or other appliance or substance. (2) An iron framework that is filled with bone ash for cupeling on a large scale. Theodolite.—An instrument used in surveying, for taking both vertical and horizontal angular measurements. An engineer's large transit, with attachments.

Thill.—See Floor.

TRQ

Thimble.—(1) A short piece of tube slid over another piece, to strengthen a joint, etc. (2) An iron ring with a groove around it on the outside, used as an eye when a rope is doubled about it.

Thirl.—See Crosscut.

Through-and-Through.-A system of getting bituminous coal, without regard to the size of the lump

Throw.—(1) A fault of dislocation. (2) The vertical distance between the two ends of a faulted bed of coal.

Thrown.—Faulted; broken by a fault.
Thrust.—Creep or squeeze due to excessive weight, hard floor, and too small pillars.

Thurl (Staffordshire).—To cut through from one working into another.

Ticketing.-English periodical markets for the sale of ores. Tie-Back — (1) A beam serving a purpose similar to a fend-off beam, but fixed at the opposite side of the shaft or inclined road. (2) The wire ropes or stayrods which are sometimes used on the side of the tower opposite the hoisting engine, in place of or to reenforce the engine

Tierras (Spanish).-Earth impregnated with mercury ore.

Tierras de Labor (Mexican).—Dirt from a stope, mixed with particles of ore. Tierras de Llunque (Mexican).-Chips made in breaking and sorting ore. Tiff.—Calcite or carbonate of lime.

Timber.—(1) Props, bars, collars, legs, laggings, etc. (2) To set or place

timber in a mine or shaft.

Timberer, Timberman.—A man who sets timber.

Time.—(1) Hours of work performed by workmen. (2) To count the

trokes of a pump or revolutions of an engine or fan.
 Tin-Can Safety Lamp. —A Davy lamp placed inside a tin can or cylinder having a glass in front, air holes near the bottom, and open-topped, making the lamp safer in a rapid current of air.
 Tin-Witts (Cornish). —Product of first dressing of tin ores, containing, also,

wolfram and sulphides.

Tip.—A dump. See Tipper, or Tipple.
Tipper, or Tipple.—An apparatus for emptying cars of coal or ore, by turning them upside down, and then bringing them back to original position, with a minimum of manual labor.

Tipple.—The dump trestle and tracks at the mouth of a shaft or slope, where the output of a mine is dumped, screened, and loaded.

Tiro (Mexican).—A mining shaft. Tiro Vertical.—A vertical shaft.

Token.—(1) A mutually understood mark placed upon a bucket of ore when it is hoisted or lowered into a shaft, to acquaint the lander or filler of some important matter. (2) A piece of leather or metal stamped with the hewer's or putter's number or distinctive mark, and fastened to the

Ton.-A measure of weight.

Top.—(1) See Roof. (2) Top of a shaft; surface over a mine.
Topit.—A kind of brace head screwed to the top of boring rods, when withdrawing them from the hole.

Torta (Mexican).-A pie or cake; the heaps of argentiferous mud that are treated in the patio process of amalgamation.

Tossing.—Shaking powdered ore in water, to effect separation of heavy and light particles.

Tovera (Mexican).—The tuyère of a smelting furnace.

Track.—Railways or tramways.

Tracking.—Wooden rails.

Train Boy.—A boy that rides on a trip, to attend to rope attachments, signal in case of derailment of cars, etc. Trip rider.

Train, or Trip.—The cars taken at one time by mules, or by any motor, or run at one time on a slope, plane, or sprag road, always together. Tram.—A mine car, or the track on which it runs.

Trammer.—One who pushes cars along the track.
Tramroad.—A mine track or railroad.

Tram Rope.—A hauling rope, to which the cars are attached by a clip or chain, either singly or in trips.

Tramway.-A small, roughly constructed iron track for running wagons or trucks on.

Transfer Carriage.—Movable platform or truck used to transfer mine cars from one track to another.

Transome (English).—A heavy wooden bed or supporting piece.

Trap.—(1) A steep heading along which men travel. (2) A fault of dislocation. (3) An eruptive rock. (4) A dangerous place.

Trap Door.—A small door, kept locked, fixed in a stoping, for giving access

to firemen and certain others to the return airways, dams, or other unused portions of the mine.

Trap Dike.—A fault (not necessarily accompanied by displacement of strata) in which the spaces between the fractured edges of the beds are filled up by a thick wall of igneous rock.

Trapiche (Spanish).—A primitive grinding mill.

Trapper. A boy employed underground to tend doors.

Traveling Road.—An underground passage or way used expressly, though not always exclusively, for men to travel along to and from their working places.

Treenail.—A long wooden pin for securing planks or beams together.

Treloobing (Cornish).—Stirring tin slimes in water.

Trend.—The course of a vein, fault, or other feature.

Tribute.—A method of working mines by contract, whereby the miners receive a certain share of the products won. Tributers.—Miners paid by results.

Trig.—A sprag used to block or stop a wheel or any machinery.

Trilla (Mexican).—The same as Torta.

Trip.—The mine cars in one train or set. See Train.

Triple-Entry System.—A system of opening a mine by driving three parallel entries for the main entries.

Triturate. -- To grind or pulverize.

Trolley.—(1) A small four-wheeled truck, used for carrying the ore bucket underground. (2) An electric motor. (3) The arm of a motor that conducts the electric current from the wire above the track to the machine.

Trommel.—A drum, consisting of a cylinder- or cone-shaped sheet-ion mantle (generally punched with holes) that revolves; used for washing

or sorting ores. Trompa (Mexican).—A funnel-shaped mouthpiece of cooled slag that forms

within a smelting furnace over the tuyere opening.

Trompe.—An apparatus for producing ventilation by the fall of water down a shaft.

Trouble.—A dislocation or fault; any irregularity in the bed.
Trough Fault.—A wedge-shaped fault, or, more correctly, a mass of rock, coal, etc. let_down in between two faults, which faults, however, are not necessarily of equal throw.

Troughs, or Thirling.—A passage cut through a pillar to connect two rooms.

Truck.—Used synonymously with Barney.

Truck System.—Paying miners in food instead of money.

Trunck System.—Paying miners in food instead of money.

Trunnions.—Cylindrical projections or journals, attached to the sides of a vessel, so that it can rotate in a vertical plane.

Trying the Lamp.—The examination of the flame of a safety lamp for the purpose of forming a judgment as to the quantity of firedamp mixed with the air.

Tub.—(1) A mine car. (2) An iron or wooden barrel used in a shaft, for holsting material.

Tubbing.—Cast iron, and sometimes timber, lining or walling of a circular

shaft.

Tubbing Wedges.-Small wooden wedges hammered between the joints of tubbing plates.

Tubing.—Iron pipes or tubes used for lining bore holes, to prevent caving. Tumbar (Mexican).—To knock down ore, etc.

timbe (Mexican).—The act of knocking down and taking out ore.

- Tranel.—A horizontal passage driven across the measures and open to day at both ends; applied also to such passages open to day at only one end, or not open to day at either end.
- Turbary.—A peat bog. Turbine. - A rapidly revolving waterwheel, impelled by the pressure of water upon blades.
- Turn.—(1) The hours during which coal, etc. is being raised from the mine. (2) See Shift. (3) To open rooms, headings, or chutes off from an entry or gangway. (4) The number of cars allowed each miner.

Turnout.—A siding or passing on any tram or haulage road.

Turn Pulley.—A sheave fixed at the inside end of an endless- or tail-rope hauling plane, around which the rope returns. See Tail-Sheave. Transle.—A revolving platform on which cars or locomotives are turned

around.

Tut Work.—Breaking ground at so much per foot or fathom.
Trygère.—The tubes through which air is forced into a furnace.
Two-Throw.—When, in sinking, a depth of about 12 ft. has been reached, and the debris has to be raised to the surface by two lifts or throws with the shovel, one man working on staging above another.

Tye.—An inclined table used for dressing ores.

Unconformability.—When one layer of rock, resting on another layer, does not correspond in its angle of bedding.

Undercast.—An air-course carried under another air-course or roadway.

Underclay.—A bed of fireclay or other less clayey stratum, lying immediately beneath a seam of coal.

Undercut.—To remove a small portion of the bottom of the bed or the underclay, so that the mass of coal or mineral can be wedged or blasted down.

Underhand Stoping.—See Stoping Underhand. Underhand Work.—Picking or drilling downwards.

Underholing, Undermining.—To mine out a portion of the bottom of a seam or the underclay, by pick or powder, thus leaving the top unsupported and ready to be blown down by shots, broken down by wedges, or mined with a pick or bar.

Underlie, or Underlay.—The inclination of a lode at right angles to its course,

or strike; the true dip.

Underviewer, or Underlooker.—An inside foreman. Unit. - (1) The unit of metals is 1% of whatever ton is used. Generally, the 20-cwt. ton, equal to 2,240 lb., is employed, but, when dealing with copper ores, the 21-cwt. ton of 2,352 lb. is taken; therefore, the respective units are 22.4 lb. and 23.52 lb. (F. Danvers Powers). (2) Ores are quoted at a certain price per unit or per cent. of valuable material in the ore. If an iron ore contains 40% of metallic iron that is worth 5 cents per unit, the value of the ore is \$2 per ton.

Unwater.—To drain or pump the water from a mine, or shaft.

Upcast.—The shaft through which the return air ascends.

Upraise.—An auxiliary shaft, a mill hole, or heading carried from one level up toward another.

Upthrow.—A fault in which the displacement has been upward.

Vapor (Mexican).-Steam; heated and stinking gas sometimes found in mines, which causes candles to burn dimly and go out.

Vaso (Mexican).—A reverberatory furnace used for smelting rich ore, or for

cupeling silver.

Vat.—Large wooden tub used for leaching or precipitation.

Vein.—See Lode. Often applied incorrectly to a seam or bed of coal or other mineral.

Veinstone.—The non-metallic portion of a vein associated with the ore.

Vena (Mexican).—A thin veln, not over 3 in. thick—a knife-blade vein.
Vend (North of England).—Total sales of coal from a mine.
Vent, or Vent Hole.—(1) A small passage made with a needle through the tamping, which is used for admitting a squib, to enable the charge to be

lighted. (2) Any opening made into a confined space.

Ventilating Column.—See Motive Column.

Ventilating Pressure.—The total pressure or force required to overcome the friction of the air in mines; the unit of ventilating pressure or pressure per sq. ft. of area multiplied by the area of the airway.

Ventilation.—Circulation. The atmospheric air circulating in a mine.

Ventilator.-Any means or apparatus for producing a current of air in mine or other airways.

Vestry (North of England).—A refuse.

Veta (Mexican).—A metalliferous vein of rock; a true fissure vein. any mineral deposit. Veta Clavada.—A vertical vein. Veta Echada.—An inclined vein. Veta Serpenteada.—A vein with frequent changes of direction or course. Veta Socia.—A vein that joins another. Veta Ramal.—A branch vein. Veta Recostada.—An inclined vein.

Viewer.—The general manager or mining engineer of one or more collieries, who has control of the whole of the underground works, and also gen-

erally of those on the surface.

Vinney.-Copper ore with green efflorescence. Vuelta (Mexican).—In refining silver, the moment when all impurities have been removed from the silver under treatment.

Vug, or Vugh (Cornish).—A cavity in the rock.

Wagon.—A mine car.

Wagon Breast.-A breast in which the mine cars are taken up to the working face.

Wailing.—Picking stones and dirt from among coals.

Wale (North of England).—Hand-dressing coal.

Walking Beam.—See Working Beam.

Wall.—(1) The face of a longwall working or breast. (2) A rib of solid coal between two breasts. Walling.—See Steening.

Walling Cribs.—Oak cribs or curbs upon which walling is built.

Walling Stage. - A movable wooden scaffold suspended from a crab on the surface, upon which the workmen stand when walling or lining a shaft.

Wall Plates.—The two longest pieces of timber in a set used in a rectan-

gular shaft.

Warners.—Apparatus consisting of a variety of delicately constructed machines, actuated by chemical, physical, electrical, and mechanical properties, for indicating the presence of small quantities of firedamp in the mines. At present, most of these ingenious contrivances are more suited to the laboratory than for practical application underground.

Warning Lamp.—A safety lamp fitted with certain delicate apparatus, for indicating very small proportions of firedamp in the atmosphere of a mine. As small a quantity as 34 can be determined by this means

mine. As small a quantity as 3% can be determined by this means. Wash.-Drift, clay, stones, etc. overlying the strata.

Washer.—A jig.

Wash Dirt.—That portion of alluvial working in which most of the gold is

Wash Fault.—A portion of a seam of coal replaced by shale or sandstone. Washing Apparatus, or Washery. -(1) Machinery and appliances erected on the surface at a colliery generally in connection with coke ovens, for extracting, by washing with water, the impurities mixed with the coal dust or small slack. (2) Machinery for removing impurities from small sizes of anthracite coal.

Washout.—The erosion of an appreciable extent of a coal seam by aqueous

agency.

Wash Place.—A place where the ores are washed and separated from the

waste, usually applied to places where the hand jigs are used.

Waste.—(1) See Goaf. (2) Very small coal or slack. (3) The portion of a mine occupied by the return airways. (4) Also used to denote the spaces between the pack walls in the gob of longwall working. (5) Refuse material.

Waste Gate (English).—A door for regulating discharge of surplus water.

Water Blast.—The sudden escape of air pent up in rise workings, under considerable pressure from a head of water that has accumulated in a connecting shaft.

Water Cartridge.—A waterproof cartridge surrounded by an outer case.

The space between being filled with water, which is employed to destroy the flame produced when the shot is fired, thereby lessens the chance of an explosion should gas be present in the place.

Water Gauge.-An instrument for measuring the pressure per square foot

producing ventilation in a mine.

Water Hammer.—The hammering noise caused by the intermittent escape of gas through water in pipes.

Water-Jacket.—A jacket filled with water, to keep cool a cylinder or furnace. Water Level.—An underground passage or heading driven very nearly dead level or with sufficient grade only to drain off the water.

Water Right.—The privilege of taking a certain quantity of water from a

watercourse.

Watershed. - The elevated land or ridge that divides drainage areas.

Waterwheel (English).-Overshot, undershot, breast wheels. A wheel provided with buckets, which is set in motion by the weight or impact of a stream of water.

Weather.—To crumble by exposure to the atmosphere.

Weather Door.—See Trap Door. Web.—The face of a longwall stall in course of being holed and broken down for removal. The length of breast or face brought down by one mining. Wedging.—The material, moss or wood, used to render the shaft lining

tight. Wedging Crib.—A curb or crib of wood or cast iron wedged tightly in place and packed, in order to form a water-tight joint and upon which tubbing

is built.

Wedging Down.—Breaking down the coal at the face with hammers and wedges instead of by blasting.

Weeldon.-Old ironstone workings.

Weigh Bridge (English).—A platform large enough to carry a wagon, resting on a series of levers, by means of which heavy bodies are weighed.

Weize.—A band or ring of spun yarn, rope, rubber, lead, etc. put in between the flanges of pipes before bolting them together, in order to make a

water-tight joint.

Well.—(1) The well of a furnace is the deepest lying portion or hollow in which the metal collects. (2) A sump, or a branch from the sump.

Whim .- A winding drum worked by a horse.

Whim Shaft.—A shaft through which coal, ore, water, etc. are raised from a mine by means of a whim.

Whin .- A hard, compact rock.

Whin Dike.—A fault or fissure filled with whin and the debris of other rocks, sometimes accompanied by a dislocation of the strata.

Whip.—A hoisting appliance consisting of a pulley supporting the hoisting rope to which the horse is directly attached.

Whitedamp.—Carbonic oxide (CO). A gas found in coal mines, generally where ventilation is slack. A product of slow combustion in a limited supply of air. It burns and will support combustion. It is extremely poisonous.

White Tin .- The commercial name for metallic tin. Whits .- See Tin-Witts.

Whole Working.—The first working of a seam, which divides it into pillars.
Wild Lead.—Zinc-blende.

Wild Rock.-Any rock not fit for commercial slate.

Win.—To sink a shaft or slope, or drive a drift to a workable seam of mineral in such a manner as to permit its being successfully worked.

Winch, or Windlass.—A hoisting machine consisting of a horizonal drum operated by crank-arm and manual labor.

Wind Bore (England).—The bottom or suction pipe of a lift of pumps, which

has suitable brass holes or perforations for suction of water or air.

Wind Gauge.—An anemometer, for testing the velocity of air in mines. Winding.—The operation of raising or hauling by means of a steam engine

and ropes, the product of a mine. Winding Engines.-Hoisting or haulage engines.

Wind Method.—A system of separating coal into various sizes, and extracting the dirt from it, which in principle depends on the specific gravity or size of the coal and the strength of the current of air.

Wind Sail .- The top part of canvas piping, which is used for conveying air down shallow shafts.

Wing Bore .- A side or flank bore hole.

Wings .- See Rests and Keeps.

Winning.—A sinking shaft, a new coal, ironstone, clay, shale, or other mine of stratified material. A working place in a mine.

Winnowing Gold.—Air-blowing. Tossing up dry powdered auriferous material in the air, and catching the heavier particles not blown away. Winze.—Interior shaft connecting levels, sometimes used as an ore chute.

Won.—Proved, sunk to, and tested.

Work.—(1) To mine. (2) Applied to mine working when affected by squeeze or creep.

Workable.—Any seam that can be profitably mined.

Worked Out.—When all available mineral has been extracted from a mine, it

is worked out.

Working.-Applied to mine workings when squeezing.

Working Barrel.-The water cylinder of a pump. Working Beam (English).—A beam having a vertical motion on a rock shaft at its center, one end being connected with the piston rod and the other

with a crank or pump rod, etc.

Working Cost.—The total cost of producing the mineral.

Working Face.—See Face.

Working Home.—Getting or working out a seam of coal, etc., from the boundary or far end of the mine toward the shaft bottom.

Working on Air .- A pump works on air when air is sucked up with the water.

Working Out.—Working outwards or in the direction of the boundaries of the collieries. Working Place.—The actual place in a mine at which the coal is being mined. Workings.—The openings of a colliery, including all roads, ways, levels,

dips, airways, etc. Work Lead.—Base bullion, silver lead.

Wrought Iron.—Iron in its minimum state of carburization.

Wythern (Wales).-Lode.

Xacal (Mexican).—A miner's cabin: a storehouse for mining goods; a shaft house.

Yardage, Yard Work.—Price paid per yard for cutting coal.

Yard Price.—Various prices, per yard driven (in addition to the tonnage prices), paid for roads of certain widths, and driven in certain directions.

Yellow Ore (Cornish).—Chalcopyrite.

Yield.—The proportion of a seam sent to market.

Zone.—In coal-mining phraseology, this word means a certain series of coal seams with their accompanying shales, etc., which contain, for example, much firedamp, called a flery zone, or, if much water, a watery zone.

INDEX.

Absolute Pressure, 195, 345.	American coals, 168.
temperature and pressure, 344, 345.	gauge wire, 208.
Abuse of instruments, 80.	measures of area, 4.
Abutments (dams), 154.	measures of length, 2.
Acceleration in jigging, 440.	measures of volume, 5.
on inclined planes, 399.	Amount crushed by rolls, 424.
Acid waters, Pumps for, 165.	of charge, blasting, 331.
Acres to square feet, 4.	of gas liberated per ton of coal,352
Adiabatic compression, 195, 198.	Analyses of American coals, 168.
Adjustable bars, 432.	Analysis of coal, 173.
Adjustment of Burt's solar attach-	Andre's formula for shaft pillars, 285
ment, 48.	Aneroid barometer, 339.
	Angle of inertia, 398.
of compass, 38.	of rolling friction, 398.
of level, 53.	
of transit, 41.	reading, 45. Annunciator system, 232.
Afterdamp, 351.	
Agonic line chart, 40.	Anthracite coal, 169.
Air and mercury columns, 347.	Cubic feet in ton of, 449.
brattice, 394.	Handling, 443.
bridges, 393.	Sizes, of 434.
columns in furnace ventilation,	Specific gravity of, 109.
384.	mining, Costs of, 323.
Compressed, 194.	mining methods, 305.
compression, Theory of, 194. compression, Horsepower neces-	Percentages of different sizes of
compression, Horsepower neces-	323, 326.
sary for, 406.	Preparation of, 442.
Air compressors, 194.	screens, Duty of, 434.
Classification of, 194.	Tests of compressive strength of
Compound, 194.	290.
Construction of, 194.	Apothecaries' weight, 1.
Cooling, 195.	Appliances in mine ventilation, 381.
Dry, 196.	Arc, Error in, 76.
Duplex, 194.	lamps, 214.
Horizontal, cross-compound,	Area, Measures of, 4.
194.	of circle, 31.
Rating of, 195.	of ellipse, 32.
Simple, 194.	of largest square inscribed in a
Stage, 194.	circle, 28.
Straight-line, 194.	of parallelogram, 28.
Vertical, 194.	of polygons, 30.
Wet, 196.	of tract of land, To find, 52.
Air currents, Conducting, 393.	of trapezium, 30.
currents, Splitting of, 373, 378.	of trapezoid, 30.
leaks, 186.	of triangle, 28.
	Areas, Calculation of, 77.
lift pumps, 164.	of circles, 1 to 1,000, Table of, 545
required for ventilation, 362.	
transmission, 196.	of circles, to 100, Table of, 561.
Airways, Similar, 372.	Arithmetic, 15.
Alabama method of mining, 297.	Arithmetical progression, 20.
Alternating current, 217.	Armature, 216.
current dynamos, 224.	Arrangement of drill holes, 244, 335.
current motors, 226.	of mine plan, 381.
Alternators, 225.	of slope tracks, 413.
Multiphase, 225, 226.	Ascensional ventilation, 381.
Single-phase, 225.	Ash (coal), 171.
Three-phase, 226.	Ashworth Hepplewhite Gray lamp
Two-phase, 226.	358.
Altitude, Effect of, on air compres-	Asphyxiation, 451.
sion, 195.	Atmosphere, Composition of, 337.
Aluminum, Electric properties of,	Weight of, 337.
200	Atmospheric pressure 339

weight, 344. Austrian measures of length, 3. Avoirdupois weight, 2. Back of Ore, Caving a, 320. Balancing a conical drum, 396. Ball mills, 427. Barometer, 339. Barometric elevations, 340.

variations, 339. Barrell, J., 62. Barrier pillars, 287. Bar signals, 235. Base lines, 46.

Atom, 341. Atomic volume, 341.

Batteries, Electric, 229. Battery cells, Composition of, 231.

water, 430. working, 307. Beams, 102, 105. Bearing in, 283.

value of masonry, 107. Bedded deposits, 279. materials, Prospecting for, 238.

Bell wiring, 230. Belting and velocity of pulleys, 193.

Bending rails, 412. Bends in pipes, 153.

Bent plumb-line method of slope sur-

veying, 73. Biram's ventilator, 387. Bitumen, Prospecting for, 249. Bituminous coal, 169.

Cubic feet in ton of, 449.

Handling, 443. Blackdamp, 350. Blacksmith coal, 173. Blake crushers, 419. Blasting by electricity, 332. Bleeding from scalp wounds, 451. Blossburg method of mining, 298. Blower fans, 386. Board measure, 13. Boiler, 176.

Care of, 185. capacity, 181. Choice of, 179, 180. cleaning, 186. coverings, 183. feed-pumps, 161.

iron, thickness required, 187. scale, 181. tests, 188.

Boltheads, Weight of, 116. Bolts per mile of track, 117. Bolts, Weight of, 116. Bonnett, 268. Bord-and-pillar, 280.

Bore-hole records, 244, 250. holes, 242.

Bottoms, Slope, 413. Boxes for electric fuses, 224. Box regulator, 375, 377. Boyle's law, 195, 345. Brass, Weight of, 111, 112, 114, 115. Brattice, Air, 394:

wheels, 157. Bridges, Air, 393. Briqueting, 448. British imperial measure (liquid and

dry), 5. measures of area, 4. measures of length, 2. measures of volume, 5.

thermal unit, 168. Brown coal, 170. Brown's method of mining anthra-

cite, 306. Brown & Sharpe gauge, 208. Buckets, Conveying, 446.

Buggy breasts, 291. Buildings, 283. Bulling, 330. Buntons, 270.

Breast boards, 270.

Burt's solar attachment, 47.

Butt cleats, 284.

Cables, Electric, 209. Cableways in mining, 278. Calculation of areas, 77. of mine resistance, 366. of wires for electric transmission,

California method of mining, 300. stamps, 428. Calorie, 168.

Calumet classifier, 435. Cams for stamps, 429. Cannel coal, 170. Capacity of boilers, 181.

of electric cables, 209. of mining machines, 337. of pumps, 161. of shaking screens, 432. of standard steel buckets, 446.

Capell ventilator, 389.

Carat. 12. Carbonic-acid gas, 350.

oxide gas, 349. Castings, Weight of iron, copper, lead. brass, or zinc, 111.

Caving a back of ore, 320. methods, 320.waste only, 320. Cells, Various types of, 231.

Centers, 59. Centigrade to Fahrenheit, 366.

to Réaumur, 366.

Centrifugal fans, 386. pumps, 164. roller mills, 426.

Chain, Surveyor's, 42. cutter machines, 337. pillars, 287.

Chains, Iron. 129.
Chamber-and-pillar method, 318.
Chambering, 330.
Channels, Flow in, 142.
Character of floor and roof on size of pillars, Influence of, 280.
Character of size of pillars, Influence of, 280.

Charging a hole, 330. Charles' law, 345.

Coefficient of contraction (water), Chemical compounds, 341. equations, 341. symbols, 341. of discharge (water), 135. Chemistry of gases, 341. Chimneys, 189. Chinese measures of length, 4. of discharge with weirs, 140. of rolling friction, 398. of roughness for water channels, Chock, 268. 144. Choice of a boiler, 179, 180. of velocity (water), 135. Coefficients of friction for various Chokedamp, 350. Churn drills, 242. materials, 95, 96. Chute breasts, 292. of friction of air in mines, 367. mining, 309. Cog, 268. Coins, 10. Circles, 31. areas of, 1 to 1,000, Table of, 545. areas of, 1 to 100, Table of, 561. Coke, 172. ovens, Cost of, 328. Circuit, Electric, 205. Coking coals, 170. Circular mil, 207. coal, Cost of, 328. Circulation of boilers, 181. Collar, 268. Circumferences, 1 to 1,000, Table of, Collimation, Line of, 53. 545. Colorado method of mining, 302. Color of coal ash, 171. 1949.
Clanny lamp, 356.
Classifers, Hydraulic, 434.
Classifying apparatus, 431.
Cleaning safety lamps, 358.
Clearfield method of mining, 295. Columns, Safe loads for, 106. Combustibles, 166. Combustion, Spontaneous, 291. Common fractions, 15. Commutator, 216. Comparison of aluminum and copper Cleats, 284. Clinometer, 44 for electric use, 209. Closed work, 279. of hydraulic formulas, 149. Close workings, Shots in, 361. of methods of shaft sinking, 262. Closing surveys, 68. of vacuum and plenum systems of Coal, 169. ventilation, 386. analysis, 173. Compass, 38. Anthracite, 169. To adjust, 38. Bituminous, 169. To use, 39 Blacksmith, 173. vernier, 39. Brown, 170. field notes, 44. Cannel, 170. Coking, 170. Composition of, 170. Complement of angle, 34. Composition of atmosphere, 337. of coals, 170. dealers computing table, 452. of forces, 95. of fuels, 169. Compound, Chemical, 341. Domestic, 173 dust, Effect of, 360. Free-burning, 170. lever, 92. Gas, 173. wound dynamos, 219. Hard, 169. Compressed air, 194. Hardness of, 171. haulage, 403. haulage problems, 404. Compressibility of liquids, 133. Iron-making, 172. Lignite, 170.
Preparation of, 418.
Prices of, 326, 327.
Production of U. S., 326. Compressive strength of anthracite, Condensers, 176. Prospecting for, 238. Running of, 312. Semianthracite, 169. Conducting power of various substances, 184. Conductors (guides), 398. (electrical), 207. for electric-haulage plants, 214. Semibituminous, 169. Sizes of, 173, 434. Soft, 169. Cone, 33. Specific gravity of, 109, 171. Splint, 170. Conical drums, 394. drum, To balance, 396. Steaming, 171. Storage of, 291. Connecting outside and inside surveys, 68. Strength of, 171. Connections for continuous-current motors, 223. washers, 436. Weight of, 170. Connellsville method of mining, 293. Coals, Cubic feet in ton of various, Constant-current circuit, 206. 109, 170. potential circuits, 206. Cockermegs, 268. power, 372.

Curves for mine roads, 411. Constant pressure, 372. pressure circuits, 206. Railroad, 78. quantity, 372. velocity, 372. Constants for nune gases, 349. for wooden beams, 103. Construction of air compressors, 194. of dams, 133. of a mine furnace, 383. Contents of a coal seam, To find, 52. of cylinders, 6. Continuous-current motors, Connections for, 223. vernier, 45. Contraction, Coefficient of (water), 135. Control of roof pressure, 284. 397. Conversion factors (hydraulic), 141. of thermometer readings, 366. tables, 7, 10. Conveyors, Horsepower of, 445. Coordinates, 51. Copper, Electric properties of, 209. Weight of, 111, 112, 114, 115. Wire, 208. Cornish pumps, 158. rolls, 423. underhand stoping, 316. Corps, Mine, 66. Corresponding mercury and air columns, Table of, 347. Corrugated rolls, 422. Decimals, 16. Cosecant, 35, 454. Cosine, 35, 453. Cost of briqueting, 449. of coke ovens, 328. of coking coal, 328. of drilling, 244-247. of haulage, 409. of mining anthracite, 322. of sinking, 263. of stamping, 430. of unloading coal, 447. of well drilling, 242. Cotangent, 35, 453. Cotangents, Natural. Table of, 464. Coverings, Boiler and pipe, 183. Coversed sine, 35. 356. Coyoting, 321. Cracking rolls, 421. Crib. 268. Cribbing, 270. Cross-section of electric wires, 207. Cross-sections, Construction of, 249. Crushing load of wood, 105. machinery, 418, 431. mills, 426. rolls, 423. rolls, Table of, 425, 426. Cube, 33.

root, 19, 545.

Cubes, Table of, 545.

coals, 449. Culm, Flushing of, 314.

Current estimates, 212.

motors, 157.

irtains, 394.

roots, Table of, 545.

Cubic feet occupied by ton of various

on slopes, Vertical, 416. Cylinder, 38. Cylinders, Contents of, 6. in a pump, Ratio of, 160. of a hoisting engine, To find size of, 397. To find contents of, in U. S. gallons or bushels, 5. Cylindrical boiler, Maximum work of, 178. boilers, Economy of, 188. drums, 394. drum, To find period of winding, rings, 34. Dams, 154. Débris, 156. Earth, 156. in mines, 133. Masonry, 156. Stone, 155. Wing, 156. Danish measures of length, 3. Darcy's formulas (hydraulic), 148. Davy lamp, 356. Débris dams, 156. Decimals of a foot for each A inch, 3. Declination, Magnetic, 39. of Polaris, 46. Deflected angle, 45. Deflections in power-transmission ropes, Table of, 122. Density of a gas, 344. Departures, 537. Deposits over 8 ft. thick, 318. Depth of shafts, Calculation of, 340. of suction, 162. Derangement of ventilating current, 359. Detaching hooks, 398. Detection of small percentages of gas. Detonation, 331. Diagram for reporting on mineral lands, 252.
Diameter of holes (blasting), 330. Diamond drill, 243. weight, 12. Dies for stamps, 429. Differential pulley, 94. Diffusion of gases, 346, 348. Dip and strike from bore-hole records. workings, Ventilation of, 382. Direct-current circuits, 210. dvnamos. 215. motors, 220. Direction of face, 284. Directions for blasting by electricity. 332. Discharge, Coefficient of (water), 135. gates (dams), 154.

through V notch, 138.

Disintegrating rolls, 423. Disk fans, 385. Distance, Errors in, 77. from center to center of breasts, **Table**, 287. Distribution of air in mine ventilation. 373. Ditches, 142 Banks of, 143. Capacity of, 143. Grades of, 143. Velocity in, 142. Division of air-current, Proportional, 375 D., L. & W. telephone system, 234. Dodge crushers, 419.

Domestic coals, 173.
Door regulator, 375, 377.
regulator, Size of opening for, 377.

Doors, 393. Double-chute battery, 309. cylindrical drums, 394.

entry, 284. Draft, 190.

Drainage in shaft sinking, 263. Drawbar pull of electric locomotives,

Drawing pillars, 289. Dredge (centrifugal pump), 164. Dredging, 279. Dressing of ores, 418. Drift of drill holes, 243. Drill, Diamond, 243.

holes, 243. holes, Arrangement of, 335. records, 244, 250.

Drilling, 242, 330. Driving the gangway, 264. Dron's formula for shaft pillars, 285. Drop for stamps, 428. Drums, Conical, 394.

Double-cylindrical, 394. for wire rope, 123. Dry measure (U. S.), 5.

Dunn's table of size of pillars, 286. Duplex pumps, 158. Dust briquets, 448. Effect of, 360.

Duty of anthracite screens, 434. of miners' inch, 137.

of stamps, 430. Dynamite, Thawing, 329. Dynamos, 215.

Alternating-current, 224. Compound-wound, 219. Series-wound, 219. Shunt-wound, 219.

Earth Augers, 242. dams, 156. Economizers, 185. Effect of altitude on air compression. 195.

Efficiency, Manometrical, 390. Mechanical, 390. of water-power, 156.

Electric blasting, 332.

Electric circuit, 205.

exploder, 332. haulage, 406.

haulage plants, Conductors for,

haulage problem, 407. locomotives, Drawbar pull of, 407. locomotives, Hauling capacity of,

power, 204. pumps, 162.

resistance, Estimation of, 209. signaling, 229-235. units, 203

wiring, 207. Electricity, 203. Electromotive force, 203, 218.

Elements, 341. in ventilation, 363.

of mechanics, 91. **Ta**ble of, 342.

Elevating capacity of buckets, 446. Elevation of rails for mine roads, 412. Elevations, Barometric, 340. Elevators, Water, 164. Ellipse, 32.

End cleats, 284. on, 285.

plates, 270. Endless-rope haulage, 401. Engine drivers, Rules for, 191.

planes, 399. Engines, Sinking, 263. Steam, 190.

Entries, Number of, 284. Equal settling factors, Table of. 439. settling particles, 439.

shadows, 47. splits of air, 374. Equations, Chemical, 341. Equilibrium of liquids, 130. Equivalent orifice, 367.

Errors, 76. in arc, 76. in distance, 77.

in measurement, 77. in surveying, 66, 76. Eschka's method of analysis for sul-

phur, 174. Establishing a meridian with solar attachment, 47.

Estimates of current, 212. Evolution, 19, 545. Excitation of dynamos, 218. Exhaust fans, 386.

Expansion of gases, 344. Exploder, Electric, 332 Exploring workings, 361.

Explosions, Exploring workings after 361.

in boilers, 179. Explosive conditions in mines, 359.

Explosives, 329. Pressures developed by, 334.

Relative strengths of various brands of, 330. Values of, 335.

Eytelwein's formulas (hydraulic), 148

Frustums, 34. Fuel dust briquets, 448.

628 Face Cleats, 284. Direction of, 284. on, 285. Factor of a mine, Potential, 367. Factors, Conversion (hydraulic), 141. Fahrenheit to centigrade, 366. Fan construction, Principles of, 391. tests, 392. ventilation, 373, 385. Fans, Ventilating, 386. Fastenings for wire rope, 126. Feeders of gas, 352. Feed-pumps, 161, 186. Feedwater for boilers, 186. Field excitation of dynamos, 218. magnet, 216. notes for outside compass survey. Filling methods, 319. Finger bars, 432. Firedamp, 351. Fires, Gob, 291. Firing a boiler, 186. blasts, 331 by detonation, 331. Fixed carbon in coal, 171, 174. Flash signals, 234. Flat deposits, 318 Flat ropes, 119, 394. Flights, Capacity of, 446. Flow of water in channels, 142, 144. in rivers, 145. through flumes, 146. through orifices, 135 through pipes, 147, 150. Flumes, 145, 443. Flow of water through, 146. Grade of, 145. Flushing of culm, 314 Foaming (boilers), 186. Forced draft, 190. Force fans, 386. Forces, Composition of, 95. Foreign coins, Values of, 11. Forepoling, 260, 270. Form of roll teeth, 422. Forms of mine timbering, 267 Formulas for air splitting, 378. for inclined planes, 399. in ventilation, 370. Foster's formula for shaft pillars, 286.

Foundations (dams), 154. Fractions, 15.

Table of equivalent decimal, 16.

Friction, 95. coefficients for air in mines, 367

in knees and bends, 153. of air in pipes, 201. of mine cars, 96. of water in pipes, 151.

Common, 15.

Decimal, 16.

Freezing process, 260.

95, 96.

Fuels, 166. Composition of, 169. Furnace stack, 385. Construction of ventilating, 383. ventilation, 373. ventilation, Air columns in, 381. Fuse boxes, 224. Fuses, 224. Fusible plugs, 186. Galvanic Action Around Boilers, 187. Gangway driving, 264. timbers, 268. Gas coals, 173 feeders, 352 Testing for, 354. Outbursts of, 352, 360. Gases, Chemistry of, 341. Diffusion of, 346, 348. enclosed in the pores of coal, 353. found in mines, 348. Pressure of, 345 Properties of, 344. Transpiration of, 346, 348. Gate for jig, 438. Gates crusher, Table of, 422. Gauge cocks, 186. of mine tracks, 411. Pressure, 185. Water, 365. Wire, 207, 208. Gauging by weirs, 138. water, 136 Gay-Lussac's law, 195, 345. Gears, Train of, 92. Gems and precious stones, Prospecting for, 241. General mathematical principles, 14. remarks on surveying, 49. Geological maps, Construction of, 249, periods, 237. Geometrical problems, 25. progression, 21. Geometry, 24. Geordy lamp, 356. George's creek method of mining, 297. Gilpin county stamps, 428. Glossary of mining terms, 565. Gob fires, 291. Gold coins, 10. Fragmental deposits, Mining of, 278. mine, Opening of, 258. Gonda type of cell, 230. Free-burning coals, 170.
gold per ton of ore, Value of, 241. Gophering, 321. Gould's formulas (hydraulic), 148. Grade of mine road, 410. Gradient, Hydraulic, 147. Graham's law, 346. coefficients for various materials. Gravity planes, 398. Specific, 107. specific, Table of, 108. stamps, 427. Gray lamp, 358.

Friction pull on endless rope, 402. Frictional resistance of shafting, 96.

Frozen ground, Mining of, 322.

Grizzlies, 431. Guibal ventilator, 388. Guides, 398. Gyratory crushers, 420. Half on, 285. Hammer crushers, 423. Handling of material, 443. Hard coal, 169, 313. Hardness of coal, 171. Haulage, 398. by compressed air, 403. Cost of, 409. Electric, 214, 406. Motor, 402. problems, 399, 407. road signals, 235.
rope, 122, 400.
Speed of, 408.
Hauling capacity of electric locomotives, 408. Hawksley's formula (hydraulic), 148. Head-bars, 431. block, 268. frames, 275, 397. frames, Sinking, 262. gears, 275. sheaves, 397. Headboard, 268. Heating surface of a boiler, 177. values of American coals, 168. Heberle gate, 438. High explosives, 329. Hill, E., 198. Hints for mining small seams, 313. to beginners in surveying, 80. Hoisting, 394. engine cylinders, 397. engine, To find size of, 396. problems, 396. ropes, Starting strain on, 126. ropes, Stress in, 123.

engine, To find size of, 396. problems, 396. ropes, Starting strain on, 126. ropes, Starting strain on, 126. ropes, Stress in, 123. Hooks, Detaching, 398. Horizontal distances, 50, 87, 537. distances, Stadia table of, 87. Horsepower for box regulators, 377. for bucket elevators, 445. for door regulators, 377. necessary to compress air, 406. of air-currents, 363. of boilers, 177. of coal conveyor, 445. of engine, 190.

of a stream, 157. required to raise water, 161. Hughes's formula for shaft pillars, 286.

Hydraulic classifiers, 434. gradient, 147. placer mining, 278. Hydraulics, 135. Hydrocarbons, 349. Hydrogen disulphide H_x S, 350. Sulphuretted, 350.

Hydrostatics, 130.

of manila ropes, 126. of stamps, 430.

I Beams, Safe Loads for, 104. Illuminating power of safety lamps, 359. Impulse wheels, 158.

Incandescent lamps, 213. Inch, Miners', 136. Inclined plane, 93.

plane, Stress in hoisting ropes on, 123.

roads, Calculation of power for, 402.

roads, Haulage on, 398. shafts, Surveying, 73.

Included angle, 45.
Incrustation and scale, 182.
Indiana method of mining, 298.

Individual angle, 45. Induction motors, 227. Inertia, Angle of, 398.

Influence of furnace stack on ventilation, 385.

of seasons on ventilation, 382. Injector, 186.

Area of nozzle of, 187.
Delivery in gallons per hour of, 187.

Inside surveys, 56, 67. Inspection of boilers, 181. Insulated wires, 212.

Interstitial currents, 439. factors, 440. Involution, 19, 545. Iowa method of mining, 299.

Iron beams, 103. for track, 117. pipe, Weight of, 113.

supports, 272. Weight of flat, 115. Weight of wrought, 114, Irregular mining deposits, 321.

Isogonic chart, 40. Isothermal compression, 195, 198.

Jaw Crushers, 419. Jeffrey-Robinson coal washer, 436. Jigs, 437. Joints in mine timbering, 267.

Kind-Chaudron Method of Sinking, 262. • Knees in pipes, 153. Koepe system of hoisting, 395.

Lamp Teats for Gas, 354.
Lamps, Arc, 214.
Incandescent, 213.
Safety, 355.
Testing, 355.
Lancashire boiler, 177.
Landings, Timbering of, 272.
Large deposits over 8 ft. thick, Mining, 318.
Latches, 413.
Latitude, 50, 537.
with Burt's solar, 48.

Launders, 443.

Law of settling particles, 439. Laws in regard to air splitting, 373. Maps, Geological, 249. Mariotte's law, 345. Marsaut lamp, 358. in regard to quantity of air, 363. of volume, 341. Leaching methods of mining, 322. Marsh gas, 348. Masonry, Bearing value of, 107. dams, 156. Lead, Weight of, 111, 113, 114, 115. supports, 272. Leclanché cell, 229. Lehigh region, Costs of mining in, Material, Handling of, 443. Mathematical signs, 14. Length, Measures of, 2. of steep pitch on inclined plane, Leveling, 53. Trigonometric, 56. Level notes, 55, 62. roads, Haulage on, 398. timbers, 268. Levels (gangways), 316, in metal mines, 264. Levers, 91. Lid, 268 Life of shoes and dies, 429. of wire rope, 123. Lignite, 170. Line shafting, 110. Liquid measure (U.S.), 5. Liquids, Compressibility of, 133. Load for wire rope, 125. that a hoisting engine will start, To find, 396. Locating errors, 76 special work, 77. Locks for lamps, 358. Locomotive haulage, 402. Logarithmic functions, Table of, 492. Logarithms, 22, 473. of numbers, Table, 473. of trigonometric functions, Table of, 492. Log washer, 436. Long-hole process of shaft sinking, horn, 285 section, 64. splice, 128. Longitudinal back stoping with filling, 319. Longwall method, 281, 302. Modifications of, 302. Timbering, 283. Loss in transmitting air, 198. of blood, 449. of head in pipe by friction, 151. of heat from steam pipes, 184. of pressure of air in pipes, 202. Low explosives, 329. Lubricants for different purposes, 102. Lubrication, 100.

Machine Mining, 336.

"apping, 74.

Magnetic prospecting, 248. variation, 39.

Malleable-iron buckets, 446.

Manometrical efficiency, 390.

Manila ropes, Power transmitted by,

Mathematics, 14 Measurement, Error in. 77. of temperature, 366. of ventilating currents, 364. Measures of area, 4. American, 4. British, 4. Metric, 4. Measures of Length, 2. American, 2. Austrian, 3. British, 2 Chinese, 4. Danish, 3. Metric, 3. Norwegian, 3. Prussian, 3. Russian, 3. Swedish, 4. Measures of volume, 5. American. 5. British, 5. Metric, 5. Mechanical efficiency, 390. mixture, 341. ventilators, 385. Mechanics, 91. Mensuration, 28 of solids, 33. of surfaces, 28. Mercurial barometer, 339. Mercury and air columns, 347. column corresponding to water column, 340. Meridians, 46. Merivale's formula for shaft pillars, Mesh for shaking screens, 433. of revolving screens for anthracite, 434. Size of, 433. Metal linings for shafts, 260. Methods and appliances in mine ven-tilation, 381. Methods of mining, 277. Alabama, 297. anthracite, 305. Blossburg, 298. Brown's, 306. California, 300. Clearfield, 295. Colorado, 302. Connellsville, 293

George's creek, 297.

Newcastle, Colo., 302.

Indiana, 298.

Pittsburg, 295.

Iowa, 299 mineral deposits, 316. Methods of Mining, Reynoldsville, Notes, Compass field, 44.
295. for outside compass survey, 44.

Tesla, Cal., 300. West Virginia, 296. Williams⁷, 312. Methods of surveying, 67.

Metric conversion tables, 7-10. measures of area, 4. measures of length, 3. measures of volume, 5.

system, 1, 2, 3, 9, 10. weight, 2.

Mil 207.

Milling system, 278. Mine-car friction tests, 98.

cars, Friction of, 96. corps, 66. dams, 133. explosions, 361. gases, 348. gases, Table of, 349.

Opening a, 257. plan, Arrangement of, 381. resistances, 364, 366.

roads, 410. sampling, 174.

telephones, 233. timber and timbering, 265.

tracks, 410. Mineral available in a prospect, 251. deposits, Methods of mining, 316.

lands, Report on, 252. Miners' inch, 136. Mining terms, Glossary of, 565.

Mixture, Mechanical, 341. Moisture in coal, 171, 174.

Molecule, 341. Money, Tables of, 10. Morris, W. H., 127. Motor haulage, 402. Motors, 214, 215.

Current (water), 157. Induction, 227. Regulation of speed of, 222. Synchronous, 226.

Movable bars, 432. pulley, 94. Mueseler lamp, 358.

Multiphase alternators, 225. Murphy ventilator, 389.

Nails, Sizes, Etc. of, 114. Nasmyth fan, 387. Natural division of air-currents, 374.

functions, Tables of, 453. gas, Prospecting for, 249. splitting, Calculation of, 374. ventilation, 381.

Needling, 268.

Neville's formula (hydraulic), 148. Newcastle, Colorado. method mining, 302.

Nitrogen, 348. Non-conductors, Relative values of,

Norwegian measures of length, 3. Notes (survey), 60.

Level, 55, 62.

on mapping, 74. Side, 60, 61. Stope-book, 62.

Transit, 60 Nozzle, Injector, 187.

Number of cars in a trip on a self-

acting incline, 399. Nuts, Weight of, 116.

Occluded Gases, 352.

Occurrence of gases in mines, 351. Ohm's law, 204. Oils for safety lamps, 356.

Lubricating, 100, 102. Open channels, 142.

work, 277.

Opening a mine, 257. in box regulators, 376. Order of drop of stamps, 428.

Ore deposits, 238. dressing, 418.

Handling of, 443. Orifice, Equivalent, 367. Oscillating bars, 432

Outbursts of gas, 352, 360. Outside surveys, 67. Overcasts, 393

Overhand stoping, 304, 317. Overshot wheels, 158.

Oxygen, 348.

Packing for Pumps, 159.

Pack walls, 283. Paint, 59.

Pamely's formula for shaft pillars, 286.

Panel system, 283. Parallel circuits, 206. Parallelograms, 28. Parallelopiped, 33. Peele, Robert, 194.

Percentage, 20 Percussion drills. 242.

Period of winding on a cylindrical drum, To find, 397.

Permitted explosives, 329. Petroleum, Fuel value of, 167.

Prospecting for, 249. Pick machines, 336.

Pillar timber, 268. and chamber, 280.

and stall, 281, 292. drawing, 289.

Pillars, 285. Weight on, at different depths, 287.

Wooden, 105. Pins, 43.

Pipes, Flow through, 147, 150.

Friction in, 151. Pressure of water in, 132.

Thickness of, 133, used for compressed-air haulage,

Table of, 406. Piston speed of pumps, 161.

Pitch at which anthracite will run, Pressure of water on plane surface, Table of, 443. 132. distance, 51. Prices per ton of coal at mines, Table. Pitching work surveys, 68. 327.Pittsburg method of mining, 295. Primary splits, 374. Prism, 33 Placer deposits, Prospecting for, 240. mining, 278. Prismoidal formula, 34. Plane trigonometry, 34. Problem in compressed-air haulage. Planes, Engine, 399. Gravity, 398. Plates, metal, Weight of, 112. Problems in geometrical construction, 25. Platform bars, 431. in haulage, 399. Plats, Timbering of, 272. in hoisting, 396. Progression, Arithmetical, 20. Plenum system of ventilation, 386. Geometrical, 21. Plotting, 49. by coordinates, 51. Properties of copper wire, 208. Plow-steel rope, 120. of materials, 107. Proportion, or Rule of Three, 18. Plugs, 186 Plumb-bob, 44. Proportional division of the air-cur-Plumbing of shafts, 69. rent, 375. Props, Undersetting of, 276, 277. Wooden, 105. Prospecting, 235. for bitumen, 249. Pneumatic method of shaft sinking stamps, 430. Pockets of gas, 352. Poetsch-Sooysmith process (freezing method), 260. for natural gas, 249. for petroleum, 249. Polaris observation, 46. Magnetic, 248. Polygons, 30. Post and breast cap, 268. Prussian measures of length, 3. Pulley, 94. Potential factor of a mine, 367. Pulleys and belting, 193. Pulverizers, 423. Pound calorie, 168. Power, Electrical, 204. Pump machinery, 158. for hoisting, 395. memoranda, 163. in mine ventilation, 367. packing, 159. of air-currents, 363. valves, 162. of a hoisting engine, To find, 396. Pumps, 158. of an explosive, 334. of waterfall, 157. Air-lift, 164. Centrifugal, 164. pumps, 162. Cornish, 158. required for inclined roads, 402. Electrical, 162. stamps, 431. for acid waters, 165. Water, 156. Power, 162. Practical examples in the solution of Simple and duplex, 158. triangles, 35. Sinking, 165. splitting of air-currents, 373. Vacuum, 164. Push button, 234. Precious stones, Prospecting for, 241. Preliminary work, 257. Preparation of anthracite, Diagram Pyramid, 33. Quantity of air required by State of, 442. of coal and ore, 418. Preservation of timber, 265. Laws, 363. Pressure, Absolute, 345. for dilution of mine gases, 363. as affecting explosive conditions, for ventilation, 362, to produce necessary velocity 361 developed by explosives, 334. at face, 363. for box regulators, 376. gauge, 185. Radial Roller Mills, 426. of anthracite coal against walls, Radii of curves, 79. Rail bending for mine roads, 412.

444.
of gases, 345.
of liquids on surfaces, 130.
of occluded gases, 352.
of steam at different temperatures, 188.
of water in pipes, 132.
on heading, 130.

Railroad curves, 78.
Rails for mine roads, 411.
per mile of track, 117.
Raises, 316.
Rails firing of bollers, 187.
method of splicing a wire rope, 127.
Rate of diffusion, 346.

elevation for mine roads, 412.

of bituminous coal against walls,

Rating of compressors, 195. Ratio of steam and water cylinders in pump, 160. Réaumur to Fahrenheit, 366. Reciprocals, 545. Recoil of an explosion, 361. Reduction of inches to decimals of a foot, 2. Regular polygon, 30. Regulation of motors for speed, 222. Regulators, 375. Relation of power, pressure, and ve-locity, 364. Relative volume of gases, 343. Relighting stations, 359. Removal of sulphur from coal, 441. Repair of boiler coverings, 187. Repairs to boilers, 180. Reporting on mineral lands, 252 Requirements of law as to splitting, Reservoirs, 154. Resistance, Electric, 203. Estimation of (electric), 209. in electric lines, 206. of soils to erosion, 143. Mine, 364. Return-call system, 232. Revolving screen mesh for anthracite. 433, 434, Reynoldsville method of mining, 295. Right-angled V notch, 137. Rings, 34. Rise workings, Ventilation of, 382. Rivers, Flow of water in, 145. Roads, Haulage on inclined, 398. Level, 398. Mine, 410. Rock-chute mining, 310. drills, 263. Handling of, 443. Roller mills, 426. Rollers, 412 Rolling friction, Coefficient of, 398. Roll-jaw crushers, 420. Rolls, 421. Amount crushed by, 424. Crushing, 423. Speeds of, 424. Teeth of, 422. Roof pressure, 280. Control of, 284. Room-and-pillar, 280. modifications of, 291. openings, 281. pillars, 286. Rooming with filling, 319. Rope haulage, 122, 400. Ropes, 118. fastenings, 126. Flat, 394. Manila, 126. Rotary crushers, 420, 422. Roughness, Coefficient of, 144. Rule of Three, 18. Rules for engine drivers, 191. Running of coal, 312. Russian measures of length, 3.

Safety catches, 398. explosives, 329. lamp oils, 356. lamps, 355, 356. lamps, Locks for, 358. lamps, Illuminating power of, 359. valves, 185. Sampling available mineral, 251. of coal, 173. Scaife trough washer, 437. Scale, Removal of, from boilers, 181. Scalp wounds, 451. Schiele ventilator, 388. Schmidt's law of faults, 239. Screens, 431, 432. Screw, 93.
Diameter and number of, 113. Seam blasting, 331. Seasons, Influence of, 382. Secant, 35, 454. Secondary splits, 374. Sederholm, E. T., 125. Semianthracite coal, 169. Semibituminous coal, 169. Series-circuits, 205. parallel method of regulation, 222. wound dynamos, 219. Settling boxes, 435. particles, Law of, 439. Shaft bottoms, Steel, 276. bottom tracks, 416. pillars, 285. plumbing, 69. sinking, Drainage for, 263. sinking, Ventilation, 263. timbering, 270. Shafting, Frictional resistance of, 96. Strength of, 110. Shafts, 259. Calculation of depth of, 340. Compartments of, 259. Form of, 259. Methods of sinking, 259. Size of, 259. Surface tracks at, 417. Table of depths of, etc., 261. Shaking screens, 432. Shanty, 268. Shearing machines, 337. Sheaves for wire rope, 123. Shoes for stamps, 429. Short horn, 285. Shots in close workings, 361. Shunt-wound dynamos, 219. Side notes, 60, 61, Signal for haulage roads, 235. Signaling, Electric, 229-235. Silver coins, 10. Similar airways, 372. Simple bell circuit, 230. Sine, 34, 453. Sines, Natural, Table of, 453. Single-chute battery, 309. entry, 284. phase alternators, 225. wire method of slope surveying,74.

Safe Loads for Cast-Iron Columns, 106.

Safe loads for I beams, 104.

Sprags, 270. Sinking a shaft, 259. Square feet to acres, 4. Cost of, 263. root, 19, 545. engines, 263. roots, Table of, 545. head-frames, 262. sets, 270. pumps, 165. Slope, 263. Speed of, 263. set system, 321. work, 318. Squares, Table of, 545. Siphons, 149. Size of engine for engine-plane haulage, 399. Squibbing, 330. Stack, Furnace, 385. Stadia measurements, 81. of hoisting engine, To find, 396. table, 86. of mesh for screens, 433 Stamps, 427. of opening for door regulator, 377. of opening in box regulator, 376. of pillars, 285. of timber, 267. heads, 429. Pneumatic, 430. Power, 431. Speed of, 429. Sizes of anthracite, percentages of Steam, 431 each, 323, 326. Standard steel buckets, Weights and coal, 173, 434. capacities of, 446. Sizing apparatus, 431. Slack, 167. Starting strain on hoisting rope, 126. Stationary screen jigs, 437. Slicing method, 319. Slightly inclined deposits, 318. screens, 431. Stations, Distinguishing, 59. Slope bottoms, 413. Establishment of, 57. level, 44. Kinds of, 57. sinking, 263 Marking, 58. Relighting, 359. surveying, 73. tracks, 413. Surface tracks at, 417. Small percentages of gas, 356. seams, mining of, 313. Soft coal, 169. Timbering of, 272. Steam, 175. engine, 190. pipe coverings, 183. different temperapressure at Soils, Resistance of, to erosion, 143. tures, 188 Solar attachment, 47. shovel mines, 278. Sole, 268. stamps, 431. Space required to store coins, 11. Steaming coals, 171. Special forms of supports, 272. Steel beams, 103. mining methods, 322. shaft bottoms, 276. work, 77. supports, 272. Specific gravity, 107. of coal, 171. tape, 43. Stems for stamps, 429. of gases, 344. Stinkdamp, 350. Stone dams, 155. of various substances, Table of, 108, 109. Stope books, 62. volume, 341. Stoping, 316. Overhand, 304. Speed of crushing rolls, 426. of drilling, 244. with filling, 319. of haulage, 408. Stoppings, 393. of revolving screens, 434. Storage, Coal, 291. of rolls, 423 Stowing, 283. of sinking, 263. Stream horsepower, 157. of stamps, 429. Strength of anthracite, 289. of water through pump passages, of electric current, 203. of materials, 102. regulation of motors, 222. of metals, 115. Sphere, 33. of roof, 280. Spikes, Railroad, 117. of shafting, 110. Sizes, etc., 114. of wire ropes, 119. Spiling, 270 Stress in hoisting ropes, 123. Strike from bore-hole records, 250. Spillways, 155. Spitzkasten, 435. Stulls, 268. Spitzlutten, 435. Stuttles, 270. Suction, 162. Splices per mile of track, 117. Splicing a wire rope, 127. Splint coal, 170. in jigging, 440. Sulphureted hydrogen, 350. Splitting formulas, 378. Sulphur in coal, 171, 174. of air-currents, 373. Removal of, from coal, 441. ontaneous combustion, 291.

Sump, 264. Theory of stadia measurements, 81. Supplement of angle, 34. Thermal unit, 168, Surface tracks for shafts and slopes, Thermometer readings, Conversion 417. of, 366. Surveying, 38. drill holes, 243. Thermometers, 366. Thickness of boiler iron, 187. methods, 67. pipe, 133. Underground, 56, 67. Thin seams, Mining, 313. Susquehanna Coal Co. (friction of Three-phase alternators, 226. mine cars), 98. Thurston, table of lubricants, 102. Swedish measures of length, 4. Ties for mine roads, 410. Switches, 413. Symbols, Chemical, 341. Timber, Crushing load of, 105. Gangway, 268. Synchronous motors, 226. joints, 267. Level, 268. Systems of working coal, 280. measure, 12. Table, Coal Dealers' Computing, 452. Placing of, 266. Tables of Barrier Pillars, 288. Preservation of, 265. batteries, 231. Size of, 267. circles, 545. Timbering, 265. circumferences and areas of cir-Forms of, 267. longwall face, 284. cles, 1 to 100, 561. combustibles, 166. Tools for sinking, 263. elements, 342 Torque, 220. hydraulic, 135-154. Track iron, 117. logarithms of numbers, 473. Tracks for shaft bottoms, 416. logarithms of trigonometric func-Mine, 410. tions, 492. Tractive efforts of compressed-air mine gases, 349. locomotives, 404. natural sines and cosines, 453. Train of gears, 92 natural tangents and cotangents, Transformers, 228. Transit, 40. rail elevations, 412. adjustment, 41. reciprocals, 545 notes, 60. squares, cubes, square roots, cube surveying, 45. roots, circumferences and areas, 545-560. Transmission of air in pipes, 196, 198. Electric, 210. Stadia, 88. pressure through water, 132. Rope, 122. strength of materials, 102-106. traverse (latitudes and depar-Transpiration of gases, 346, 348. tures), 537. Transporting a 450. wounded person. well-known shafts, 261. (For tables not enumerated above see the Transverse rooming with filling, various subjects.) 319. Tail-rope haulage, 400. Trapeziums, 30 Tamping, 331. Trapezoids, 30. Tangent, 35, 453. Tangents, Natural, Table of, 464. Traverse tables, 537. Traversing a survey, 51. Treatment of injured persons, 449. Tappets for stamps, 429. Teeth for rolls, 422. persons overcome by gas, 451. Telephones in mines, 233. Tremain stamp, 431. Telpherage, 278. Trestles, 274. Temperature, Absolute, 344, 345. Triangles, 28, 35. Measurement of, 366. Trigonometric leveling, 56. Tension on hauling rope, Calculation Trigonometry, 34. of, 401 Triple entry, 284. Trommels, 433. Tertiary splits, 374.
Tesla, Cal., method of mining, 300.
Test of mine-car frictions, 98. Trough washer, 437. Troy weight, 1. Testing for gas by lamp flame, 354. lamps, 355. Tests, Boiler, 188. True north from Polaris, 46. with the Burt solar, 48. T-square method of plumbing shafts, Fan, 392 of compressive strength of an-Tunnels, 265. thracite, 290. Flow of water through, 147. Turbines, 158. Thawing dynamite, 329. Theory of air compression, 194. Turnouts, 413

Two-phase alternators, 226.

jigging, 439.

Undercasts, 393. Undercutting, 283. Underground prospecting, 239. supports, 267. surveying, 56, 67 Underhand stoping, 316. Undersetting of props, 267, 276, 277. Undershot wheels, 157. Unequal splits of air, 374. Units of electricity, 203. of resistance, Electric, 203. of work, Electric, 205. Unloading coal, Cost of, 447. Useful horsepower during winding, To find, 397. Use of compass, 39. Vacuum Pumps, 164. Vacuum system of ventilation, 386. Value of a fuel, 166. Values of explosives, 335. Valves, Pump, 162. Safety, 185. Variation, Barometric, 339. of ventilation elements, 372. To turn off the, 39. Velocity, Coefficient of (water), 135. of air-current, 364. of a water jet, 135. of water through pump passages, Ventilating currents, Measurements of, 364. Ventilation elements, 363. elements, Variation of, 372. formulas, 370. in shaft sinking, 263. methods and appliances, 381. of Mines, 337 of rise and dip workings, 382. Ventilators, Mechanical, 385. Verniers, Reading, 39. Versed sine, 35. Vertical angle, 51. curves on slopes, 416. distances, 50, 87, 537, distances, stadia table, 87. V Notch, 137. Volatile combustible matter of coal, 171, 174. Volume and absolute pressure, 345. and absolute temperature, Relation of, 345. Atomic, 341. Measures of, 5. Specific, 341. Waddle Ventilator, 387. Wall plates, 270. Wardle's formula for shaft pillars, 285. Washers, Ore and coal, 436. Weight of, 116. Waste gates, 146.

Weight, Apothecaries', 1. Atomic, 344. Avoirdupois, 2. Metric. 2. Troy, 1. Weight of atmosphere, 337. bolts, 116. castings, 111. chains, 130. coal, 170. flat wrought iron, 115. gases, 344. iron pipe, 113. materials, 102 112 standard steel buckets, 446. water, 107, 130. wire ropes, 119. wrought iron, 114. Table of, 287. Weights and measures, 7. Weir discharge, 140. Weirs, 138. Well drilling, Cost of, 242. Wheel and axle, 92. Wheels, Water, 157. Breast, 157 Impulse, 158 Overshot, 158. Turbines, 158. Undershot, 157. Whitedamp, 349. Whiting system of hoisting, 395. Williams' method of mining, 312. Wing dams, 156. Winslow, Arthur, 81. Winzes, 316. Wire gauge, 207. nails, 114. Wire rope, 118. fastenings, 126. ways, 155. Water, Battery, 430. Life of, 123. Size of drums for, 123. buckets, 164. splicing, 127. column corresponding to Weight and strength of, 119. mercury column, 340. Wire. Weather-proof. 212.

Water elevators, 164. flow through orifices, 135. gauge, 186, 365. Gauging, 136. level, 186. memoranda, 163. power, 156. raised by single-acting lift pump. weight of, 107, 130. Waterproof push button, 234. Waterwheels, 157. See Wheels. Watt-hour, 205. Weather-proof wire, 212. Wedge, 93. boltheads, nuts, and washers. 116. plates of steel, wrought iron, etc., Weight on pillars at different depths, West Virginia method of mining. West Vulcan telephone system, 234.

Wiring, Bell, 230.
Electric, 207.
Wolf lamp, 358.
Wood, Crushing load of, 106.
fuel, Value of, 166.
screws, 113.
Wooden beams, 102.
Constant for 103.

Constants for, 103.

Wooden dams, 154.
Working load for wire rope, 125.
Methods of, 277.
Wrought iron, Flat, 115.
Wyoming region, Costs of mining in

Zinc, Weight of, 111.



- 666